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ABSTRACT

One of the most valuable resources for obtaining exemplary instructional materials for the classroom is teachers. This booklet contains numerous laboratory activities compiled from submissions by recipients of the National Association of Biology Teachers' Outstanding Biology Teacher Award (1989-92). Topics are sorted into the following sections: (1) "Classification and taxonomy"; (2) "Genetics"; (3) "Variation and diversity of life"; (4) "Life processes"; (5) "Developing research and writing skills"; (6) "Student projects"; (7) "Using food in the classroom"; and (8) "Botany." (ZWH)

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Favorite Labs From Outstanding Teachers

Volume II

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Edited by Linda R. Sanders, Ph.D.

Published by the National Association of Biology Teachers

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Volume II

Compiled from submissions by recipients of the National Association of Biology Teachers' Outstanding Biology Teacher Award (1989-92)

Edited By
Linda R. Sanders, Ph.D.

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When not involved in academic work, Sanders enjoys traveling, walking, and reading.

Acknowledgments

The Outstanding Biology Teacher Award recipients who submitted their lab activities for consideration for this monograph deserve special praise for their innovative ideas and for their patience through the long selection and publication process. The editor would like to thank the Publications Department staff of the National Association of Biology Teachers, especially Sherry Grimm for her help and guidance in seeing this publication through to completion. Thanks also go to Patricia McWethy, NABT Executive Director, for her help and support with this endeavor.

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Introduction

The Outstanding Biology Teacher Awards (OBTA) are given to exemplary biology teachers who have a wealth of pedagogical and content knowledge. As with other professional experts, these educators are very willing to share their knowledge and expertise with others. Since the first volume of this publication was so successful and well received, the NABT Publications Department has decided to offer Volume II. Biology teachers everywhere have found the laboratory activities in Volume I to be valuable in the classroom, and hopefully this second volume will prove to be an equally useful classroom resource.

Many excellent labs were submitted from many outstanding teachers, and the selection process was not easy. The labs chosen for this volume were selected because they reflect recent trends in science education or they represent innovative techniques around traditional ideas. Many of these are original labs developed by the teacher/author and represent an attempt to make science more relevant to the everyday life of students and to incorporate societal issues and concerns into classroom work. Other activities reflect up-to-date trends in technology, such as DNA fingerprinting. Also included are activities which emphasize student writing and research skills.

As the review process evolved, certain themes were selected: classification and taxonomy, genetics, variation and diversity of life, life processes, developing research and writing skills, student projects, using food in the classroom, and botany. These are viewed as fundamental topics that would be of interest to biology and life science teachers and could be incorporated into a variety of science courses. It is hoped that teachers will find these lab activities ready to use in their classrooms with little or no modification or adjustment.

Section I - Classification & Taxonomy

Constructing Dichotomous Keys

Sharon Zupo
Salem, Oregon

This lab introduces the concept of dichotomous keys and their construction. Basic skills of defining, organizing, and classifying simple classroom items by their common characteristics will be accomplished by students.

GRADE LEVEL
Grades 9–12

MATERIALS (per group of 2–3 students)
- Glass beaker (or baby food jar)
- Piece of chalk
- Rubber band
- Dissecting needle
- Metal tweezers
- Metal pin
- Glass rod
- Scissors
- Cork
- Nail

PROCEDURE FOR THE TEACHER
Before the lab – The teacher should demonstrate the making of a dichotomous key on the board by having the students assist in constructing a key of the students in the class. Ask for common characteristics that will separate them into approximately two equal groups. Usually male vs. female becomes the first suggested choice, followed by tall vs. short or dark vs. light hair. This can be used to reinforce the difference between observation and inference and the use of quantitative observations instead of relative terms. It is usually sufficient to complete 5–7 students in the key on the board to demonstrate the process. Usually students choose color of clothing, the wearing of glasses or not — characteristics that easily can be observed by all members of the class. Avoid characteristics such as color of eyes, the wearing of orthodontia, etc., which are difficult to observe.

Day of the lab – Hand out the beakers with the 9 objects to every 2 students. Write the 10 object names on the board. Working together, the students should create a dichotomous key of the 10 objects using common characteristics that are observations (not "... is used for dissections"). When they have completed the task, use their key to physically move the objects into subsequently smaller groups as per their instructions to visually demonstrate their key to them. Then have the students make a new dichotomous key of the same 10 objects using all new criteria. This will be a good challenge!

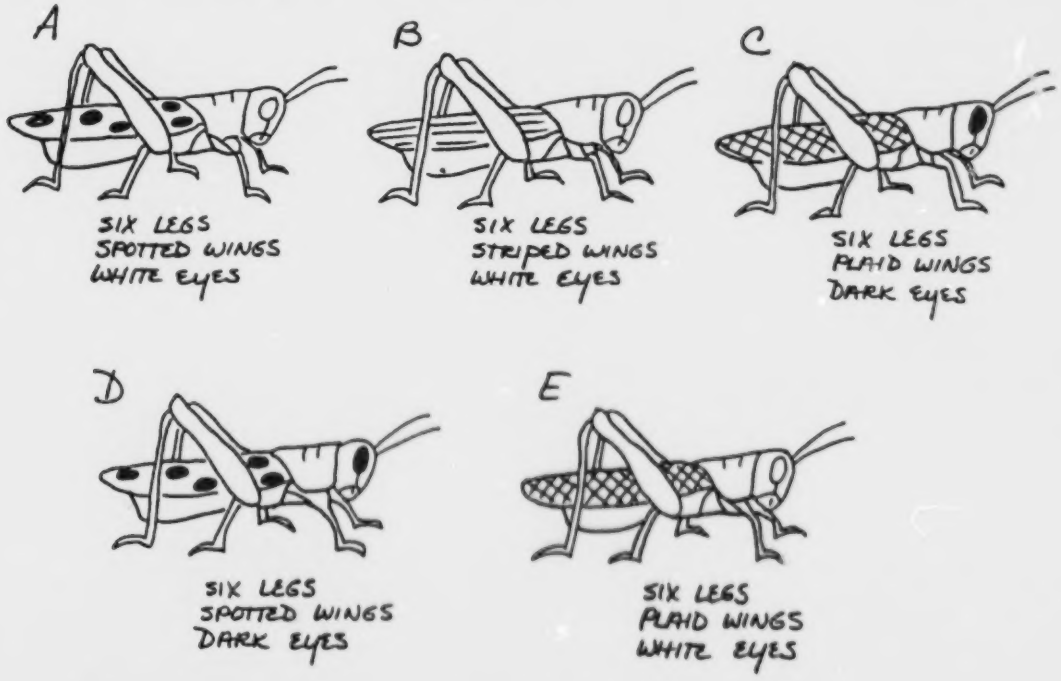
HELPFUL HINTS
Remind the students to use quantitative observations whenever possible. Avoid inferences and relative terms. (Instead of tall vs. short, use 5'6" and over vs. under 5'6"). The dissecting needle contains both wood and metal, so students' characteristics should indicate this. An example of the dichotomous key format is:
- 1A ... Made up entirely of metal ... go to step 2
- 1B ... Doesn't contain metal ... go to step 5
- 2A ... 5" long and over ... tweezers
- 2B ... Under 5" long ... go to step 3
- 3A
- 3B

Accompanying sheets included with this lesson are supplemental sheets which can be given as additional exercises or tests.

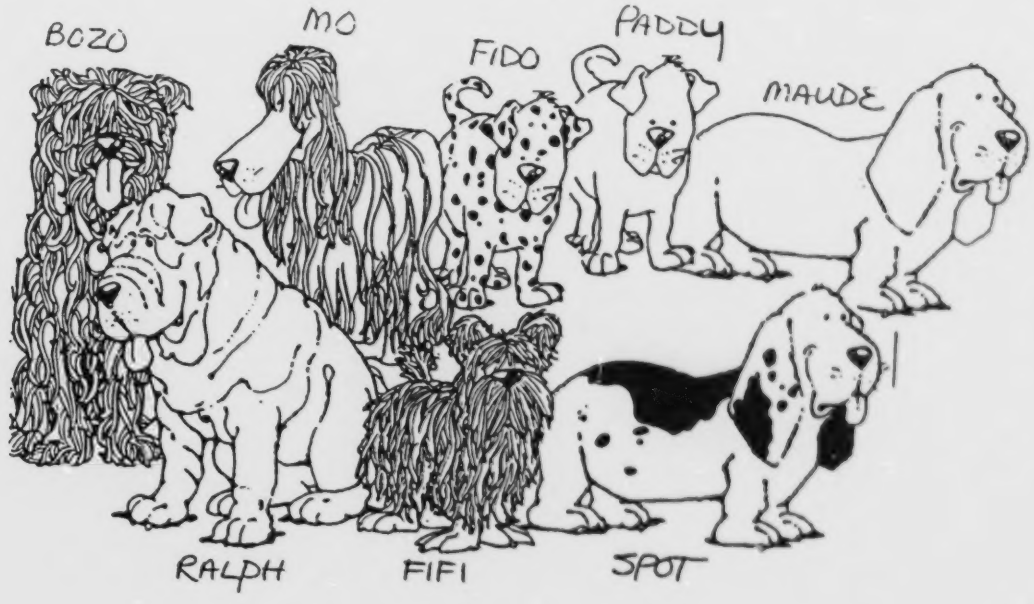
SUMMING UP
Students enjoy the hands-on experience of making the dichotomous keys. Physically moving the objects with

common characteristics into progressively smaller groups visually demonstrates the concept of the key. Students soon realize there is no one correct method to construct a key. Books that include keys to mushrooms, flowering plants, birds, insects, trees, etc., can be set out in the classroom to demonstrate the practical use of what the students have just completed. They may also be assigned an organism to key out.

The following grasshoppers were captured by a student on a field trip. He made drawings and observations on each. Make a dichotomous key using only the observations listed.

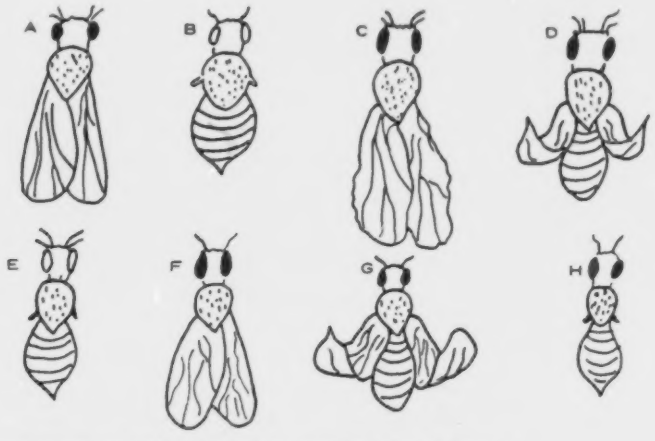


Make a dichotomous key of the eight dogs found in the picture. You may choose your own characteristics.



The following types of flies were found in the darkest jungles of Africa. Below are the characteristics of each:

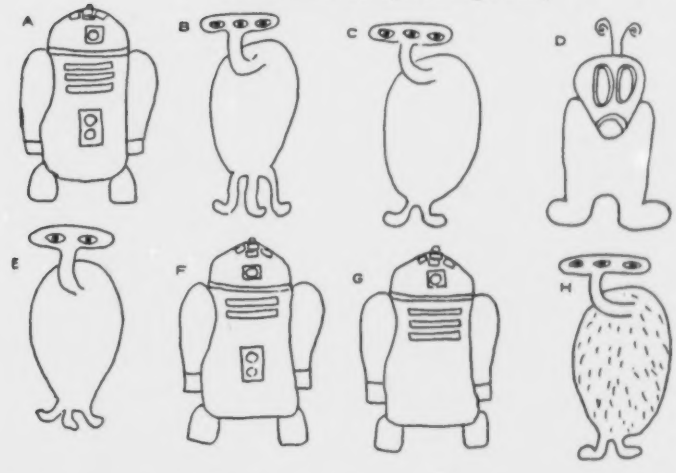
TYPE A	2 pair antenna, lanceolate wings, black eyes, striped body
TYPE B	1 pair antenna, no wings, white eyes, striped body
TYPE C	2 pair antenna, lanceolate scalloped wings, black eyes, striped body
TYPE D	2 pair antenna, curly wings, black eyes, striped body
TYPE E	2 pair antenna, no wings, white eyes, striped body
TYPE F	1 pair antenna, lanceolate wings, black eyes, striped body
TYPE G	1 pair antenna, curly wings, black eyes, striped body
TYPE H	1 pair antenna, no wings, black eyes, striped body



MAKE A KEY AND CLASSIFY THESE TYPES OF FLIES

Luke, Obi-Wan Kenobi and their sidekicks, R2-D2 and C-3P0, in their mission to save the Princess Leia from the evil Galactic Empire commanded by Darth Vader, travel to a spaceport bar where they encountered the following creatures--as yet unnamed. Make a dichotomous key below <u>using only the information given</u>. Good luck and may the force be with you!!!

A - metallic, 3 memory banks, radio receiver and transmitter
B - humanoid, 3 eyes, 3 legs
C - humanoid, 3 eyes, 2 legs
D - humanoid, 2 eyes, 1 pair antenna
E - humanoid, 2 eyes, 3 legs
F - metallic, 2 memory banks, radio receiver and transmitter
G - metallic, 3 memory banks, no radio receiver and transmitter
H - humanoid, 3 eyes, 2 legs, hairy



Phylogeny: The Relationship Between Taxonomy & Evolution

Jon Fiorella
Bedford, New York

Taxonomy helps us to investigate the past. The similarities of organisms alive today can be used to infer evolutionary relationships and can tell us a lot about their evolution from earlier forms. In most cases, organisms that are most similar in their present forms are most closely related in an evolutionary sense. A diagram of these relationships is called a "phylogenetic tree."

OBJECTIVE

The purpose of this lab is to give students the opportunity to gain experience in classifying and to show the relationship between taxonomy and evolution. In small groups, they will develop phylogenetic trees to show the evolutionary relatedness of common household hardware "organisms."

GRADE LEVEL

Grades 7-12, depending on the level of detail required by the teacher.

MATERIALS

Packets of common household hardware. These packets should all be the same and should include such things as screws, nails, tacks and fasteners. Ziploc® plastic bags work well and are obtainable at any supermarket. (Paper bags also work well; sharp objects don't poke through as easily, and they can be held closed with clothespins or paper clips. Also, paper bags prevent the students from seeing the contents until the appropriate moment.)

PROCEDURE FOR THE TEACHER

Before the lab – The teacher should organize the packets so that each has the same pieces (20-25) of hardware. Each group of four students should receive one packet.

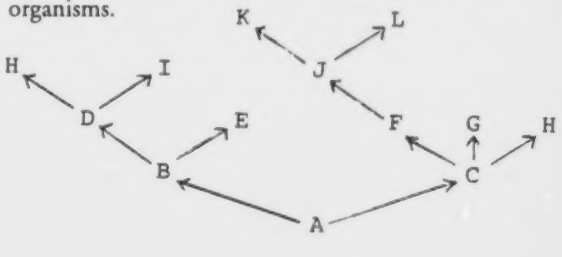
Day of the lab – The teacher should explain the lab in such a way that the students realize that there is no one "right" answer. The critical thinking processes and the ability to justify the classification pattern should be emphasized. It is very common for students to disagree among themselves, so they must be prepared to compromise. Looking at another group's work will not be useful as the other group may be using a different system of classifying.

PROCEDURE FOR THE STUDENT

• Study the packet of household hardware and arrange the pieces into groups of similar objects. The groups should be organized based on the structure of each piece and not on its function. Form at least two or three groups.

• For each piece of hardware, make a list of three characteristics that could be used to classify it (e.g., thin stem, flat head, silver, threaded, etc.).

• Now pretend that these are living organisms. For each group, decide which organism seems to be the simplest. Which one is the most advanced? Make an arrangement of the pieces to show how these organisms may have evolved from the simplest to the most advanced forms. Is there one "organism" that could belong to all the groups? This would be the ancestor of all the others. Be aware that a "tree" of evolutionary relationships is being created, so it is necessary to show branching (two or more organisms can evolve from the same ancestor). The classification scheme may also include extinct organisms.



• After the organisms have been arranged into an evolutionary tree, draw them. It is not necessary to be an artist to do this, but care must be taken to include the essential details of each organism in the drawings.

HELPFUL HINTS

• This lab exercise will show a relationship between taxonomy and evolution. Use this activity as an introduction or as a summary if the higher concepts necessary have already been convered.

• Be prepared for lively discussion while the students are trying to come up with a pattern that they can all agree on.

• Groups of 3-4 students seem to work best. In larger groups, some people get left out of the process; in smaller groups, they tend to come to an agreement too soon.

• Encourage them to consider branching. Too often students tend to classify in a linear fashion only.

• When reviewing this lab, have the different groups compare their results. Even though all the groups used identical packets, many different classification schemes resulted.

• Encourage them to justify the logic they used. Point out that scientists sometimes disagree on schemes of classification, and the more information at their disposal, the more accurately they tend to classify.

An example of this is the question of the classification of the giant panda. Originally this panda was grouped with the bears, but there was dispute that it might be more closely related to the lesser panda, which belongs to the raccoon family. After detailed studies of their anatomies were performed, it was decided that the giant pandas were more closely related to the bears. This conclusion was later verified with studies of the DNA and proteins (Curtis & Barnes 1989).

• Using more than three characteristics to classify each piece of the hardware may also be useful.

• Advanced classes can carry this lab further by developing an actual classification scheme from phylum to species. A key can be created for the purpose of classifying any new pieces of hardware that might be "discovered" later.

• Nails, screws and tacks can be sharp!! Remind students to treat these "organisms" with respect.

• Use a variety of sizes of the hardware but stick with ones on the larger end of the scale. The very small ones are harder to handle and get lost too easily.

SUMMING UP

Teachers may want to use the following questions as a part of the lab summary along with their own.

1. What basis did you use in classifying your organisms?
2. How did you decide which organisms were most primitive? Could they have actually been the most advanced? Why or why not?
3. How did you decide which organisms were most advanced?
4. What does the science of taxonomy tell us about evolution?
5. Why did different groups have different phylogenetic trees?
6. Which organisms on your evolutionary tree are extinct? How do you know this?
7. Which organisms are the most closely related? Which are most distantly related?

REFERENCES

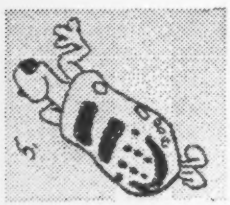
Curtis, H. & Barnes, N.S. (1989). *Biology* (5th ed.). New York: Worth Publishers, Inc.

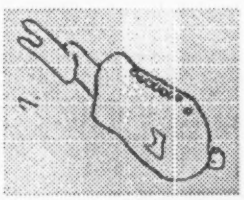
Developing a Cannamacule Key

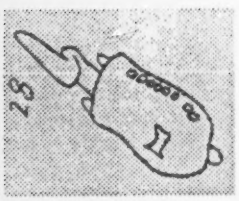
Kathryn Green
Hillsboro, Oregon

The 29 cannamacules are imaginary "critters." Although the original source has long since been lost, and the creator's intent is unclear, these cannamacules work exceptionally well for the following taxonomy activity. Each of the 29 is different, but all show various degrees of similarity that might be typically seen in a group of related biological organisms.

Examples are shown below.







OBJECTIVES

- To give the student further practice in manipulating groups and using the process of elimination.
- To reinforce observation skills and the use of descriptive terminology.
- To give students insights into why some classification keys appear vague as to the author's meaning.
- To allow the teacher to have an easy, accurate method of assessing student development of the required classification skills.

GRADE LEVEL

High school age students (Grades 9-12)

PROCEDURE FOR THE TEACHER

Before beginning the following activity, the teacher should spend a short amount of time formulating the ground rules for a dichotomous key. These include (1) not having any more than two choices at any one step of the key and (2) having each choice end in either a name or a number which sends the user on to another part of the key. The next step is to demonstrate the actual process of key construction.

The teacher might start this by asking 10 students to contribute one of their shoes, throwing one of his/her shoes in as well. Using the pile of shoes as the data and starting with the large group of 11, continually divide the group into smaller and smaller ones. This is very visual and involves all the students in the class. As the students make the decisions for establishing each new group, the teacher records their decisions in dichotomous key format on the chalkboard. In this way, a sample key is completed, demonstrating skills necessary in later activities.

PROCEDURE FOR THE STUDENT

Students are given only pictures of the 29 cannamacules with no descriptive dialogue. Their task is to individually construct a workable dichotomous key for all 29. They are told they may call the "critter" parts by any term they wish as long as they understand the term's meaning. They are, however, not allowed to include any clarifying illustrations as part of their key.

HELPFUL HINTS

The teacher should allow two class periods for this activity. It does take them a little time to get under way and gives the teacher enough time to touch base with every student to make sure the proper procedure is being followed. By allowing the students to work on their own at this point and making it essential that they

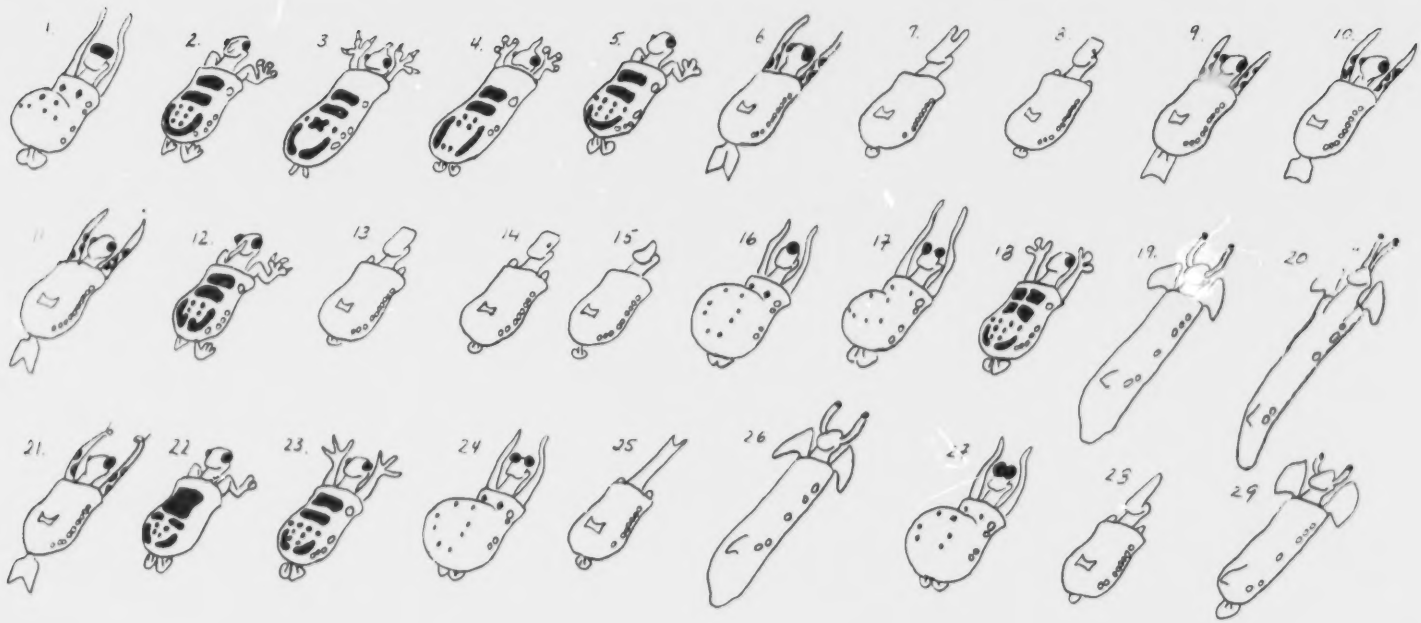
have a workable product in a specified length of time, the teacher can quickly determine who needs further help and who is capable of proceeding without it. As students finish their key, the teacher can encourage them to check its workability by providing them with a set of pictures with original numbers on the back.

SUMMING UP

This activity is fun for the students, presenting them with the challenge of constructing a key with unfamiliar objects. It is also good practice in learning about classification and taxonomy through the development of dichotomous keys.

Cannamacule Student Handout

Construct a workable dichotomous key for all 29 cannamacules.



Classification Concentration

Catherine Ross
Birmingham, Michigan

Usually, students (and many teachers) dread learning even the most basic taxonomy. However, as biology teachers attempt to avoid monotonous memorization of vocabulary lists and yet have students learn the core biological content, some vocabulary is essential. In the same way, a basic understanding of classification is necessary to appreciate the unity in diversity of life on this planet as well as other biological themes, such as the continuity of life from the molecular level to evolution or changes in living things over time.

By using 10 familiar representatives of the animal phyla, students begin to learn basic morphology and to see the major patterns and unity in the different phyla. And by learning about the example phyla, students become cognizant of more than one million of Earth's creatures.

OBJECTIVES

- To learn the morphological characteristics of animal classification.
- To learn the major animal phyla and their characteristics.
- To appreciate the unity in diversity and patterns of life on Earth.
- To have fun in group or individual competition as the students learn.

MATERIALS

- Student information sheets (Figures Ia and Ib) and charts (Figures IIa and IIb).
- Classification Concentration "cards" (Figures IIIa and IIIb) in two colors for individuals, teams, or groups. (One half of an envelope forming a pocket is great for "card" storage and eliminates "confetti" on the classroom floor.)
- Optional and helpful: animal specimens or pictures.

PROCEDURE FOR THE TEACHER

- Run off student copies and transparencies of charts.
- Display specimens or pictures of "unknown" animals.

PROCEDURE FOR THE STUDENT

- Cut game cards.
- Spread on table surface with picture side down.
- Pick up structural characteristic and try to match with correct example animal.
- Record "match" as a point and take another turn.
- If no "match" is made, turn passes to next student or team.
- Team or student with most points after game wins "bonus points" (and usually does great on test).

QUESTIONS TO CONSIDER

1. Try taking a "quiz" by reassembling structural characteristic cards (Figure IIIa) in pre-cut formation under each example animal.
2. Identify unknown specimen or picture (on teacher's demo table) from phylum and at least three structural characteristics. What kind (if any) internal organs does it have?
3. How do structural characteristics help you understand evolution of life on Earth?
4. Develop a concentration game for one or all the other kingdoms.

HELPFUL HINTS

Before beginning this activity, the teacher may want to discuss the characteristics used in the game using examples shown on the overhead projector. (A garden hose and a paper bag make a clear demo of digestive system structure, and a soft, partially-deflated plastic ball helps to illustrate body layers.) The teacher may also want to refer to patterns learned when studying physiology, genetics and evolution.

Figure Ia

UNITY IN DIVERSITY
SUMMARY OF KINGDOM CHARACTERISTICS
(partial list)

ANIMALS

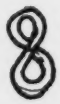
CHARACTERISTIC	EXPLANATION	SYMBOL
SYMMETRY		
Radial Symmetry	structures on a circular plan usually stationary organisms usually aquatic	
Bilateral Symmetry	distinct right and left sides usually mobile, w/paired organs terrestrial and aquatic	
BODY LAYERS		
Few to Two Layers	no true body cavity primitive system with little specialization or flexibility	0-2
Three Layers	body cavity three embryonic layers give rise to complex systems and much specialization	3
BODY OPENINGS or DIGESTIVE SYSTEM		
One Opening or sac	food and waste enter and exit through one opening usually aquatic	
Two Openings or tube	separation of food and waste usually organ specialization terrestrial and aquatic	
HABITAT		
Colonial	simple animals, share organs usually stationary	
Independent	usually have specialized organs are mobile	
TRANSPORT SYSTEM		
Diffusion	molecules move from cell to cell limits organism size and are usually aquatic	
Vascular	tubes transport food, oxygen all through organism supports diversity and large size terrestrial and aquatic	

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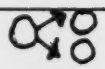
Figure Ib

OTHER KINGDOMS

CHARACTERISTIC	EXPLANATION	SYMBOL
CELL STRUCTURE		
Prokaryotic	lacks nuclear membrane very small size	
Eukaryotic	true nucleus and other membrane bound organelles	
NUTRITION		
Autotrophic	photosynthesize with chlorophyll using sunlight (producers)	
Heterotrophic	cannot photosynthesize depend on producers for food (are consumers)	
TRANSPORT		
Diffusion and Non-Vascular	food and waste move through cell membranes (limits size and habitat)	
Vascular	have tubes to transport food and water throughout organism	
REPRODUCTION		
Asexual	reproduces by simple cell diffusion	
Sexual	two organisms contribute to offspring	
Alternation of Generations		
Haplontic	most of organism's life cycle is with haploid cells	n
Diplontic	most of organism's life cycle is with diploid cells	2n

BEST COPY AVAILABLE

Figure IIa

SURVEY OF THE MAJOR ANIMAL PHYLA

NAME _____
HOUR _____

For each of the following, give an example animal, tell its symmetry, (radial, bilateral, or none), number of body layers,(0-3) and body openings, (0, 1-sac, or 2-tube).

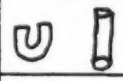
PHYLUM	SYMMETRY	BODY LAYERS	BODY OPENINGS	OTHER
		0, 2, 3		
1. PORIFERA				
2. COELENTERATA				
3. PLATYHELMINTHES				
4. ASCHELMINTHES				
5. ANNELIDA				
6. MOLLUSCA				
7. ARTHROPODA Class a.Crustacea b.Arachnid c.Insecta				
8. ECNINODERMATA				
9. CHORDATA Class a.Osteichthyes b.Amphibia c.Reptilia d.Aves e.Mammalia				

Figure IIb

SURVEY OF THE OTHER KINGDOMS

NAME _____

HOUR _____

For each of the following: give an example, list structure (prokaryotic or eukaryotic), nutrition (heterotrophic or autotrophic), transport (diffusion, non-vascular, or vascular), and reproduction.

PHYLUM	STRUCTURE	NUTRITION	TRANSPORT	REPRODUCTION	
MONERANS 1. Schizomycophyta 2. Cyanophyta					
PROTISTA 3. Chrysophyta					
FUNGI 4. Myxomycophyta 5. Eumycophyta 6. Lichens					
PLANTAE 7. Chlorophyta 8. Phaeophyta 9. Rhodophtya 10. Bryophyta 11. Tracheophyta					

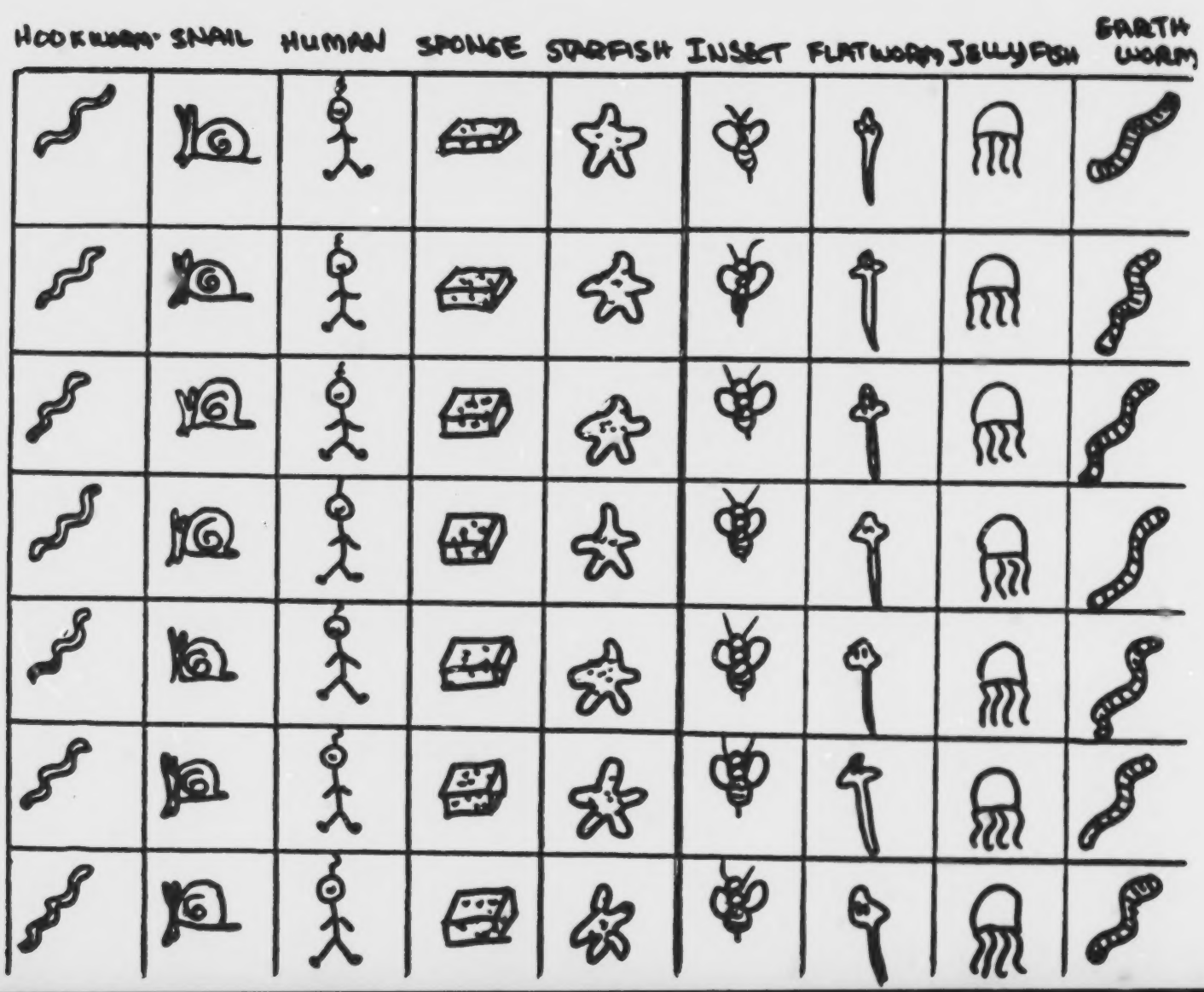
Figure IIIa

ANIMAL CONCENTRATION GAME

To Play: After you cut this sheet and Figure IIIb, turn them all face down on the table and match pictures to words or numbers.

	HOOKWORM	SNAIL	HUMAN	SPONGE	STARFISH	INSECT	FLATWORM	JELLYFISH	EARTH WORM
PHYLUM	ASCHEL-MIN-THES	MOLLUSCA	CHOR-DATA	PORI-FERA	ECHINO-DERMA-TA	ARTH-ROPODA	PLATY-HEL-MIN-THES	COEL-ENTER-ATA	ANNEL-IDA
BODY PLAN	2 OR	2 OR	2 OR	MANY PORES	2 OR	2 OR	1 OR	1 OR	2 OR
SYMMETRY	BILAT.	BILAT.	BILAT	NONE	RADIAL	BILAT.	BILAT.	RADIAL	BILAT.
LAYERS	3 layers	3 layers	3 layers	2 layers	3 layers	3 layers	3 layers	2 layers	3 layers
COMPLEX-ITY OR PHYLOGENY	4	6	9	1	8	7	3	2	5
PHYLUM CHARAC-TERISTICS	ROUND UNSEG-MENTED WORMS	SOFT UNSEG-MENTED MANTLE	DORSAL NERVE CHORD VERTE	LIKE A COLONY	SPINY SKIN 5's	EXOSKEL SEGMEN-TED	FLAT UNSEG-WORMS	STING-ING CELLS	SEGMEN TED WORMS
MAJOR HABITAT	H_2O	H_2O + LAND	LAND	H_2O	H_2O	LAND	H_2O	H_2O	H_2O + LAND

Figure IIIb


HOOKWORM
SNAIL
HUMAN
SPONGE
STARFISH
INSECT
FLATWORM
JELLYFISH
EARTH WORM

Section II - Genetics

Indian Corn & the Genetic Mystery

Don Bogdanske
Ripon, Wisconsin

This lab activity should be used following a discussion of genetics and the occurrence of an organism's traits. Students should have performed exercises in Mendelian inheritance and understand that there are dominant and recessive conditions that influence a new individual's genetic makeup.

In addition to simple genetic combinations, there exist complex patterns of inheritance. Singleton (1967) states that in many organisms the need for more than the typical alleles for a given trait is essential for the actual survival of the organism. In the case of rabbits, this condition is observed in their coat color. In corn, which is the subject of this lab exercise, multiple alleles are involved in the color of the kernel as it develops.

Actually, there are several series of multiple alleles influencing the corn plant and its kernels. Each of these alleles may occur at different loci, and yet they may interact. In 1947, Barbara McClintock proposed that genes could move within and between chromosones. The primary control of aleurone color in corn is due to three different genes, R, Pr and C, each of which may occur in a number of alleles. When these alleles interact, they change the outcome of the kernel and, of course, the normally predictable traits and phenotypes.

Students already realize that dominant traits mask the recessive condition. Corn kernels from garden-grown varieties provide a wonderfully challenging exercise which allows the student to really solve a problem by collecting observable data and drawing conclusions.

In the initial discussion of the exercise, students will be told that there are usually two colors of corn kernels that they can obtain -- yellow and white (Y_ and yy). They are also told that these genes influence the color of the endosperm. The reason these kernels stay these colors is because they lack any of the other genes that cause pigmentation or have only the recessive genes for pigmentation (pr or rr).

One other item of interest is that within the kernel there is another type of element that controls the pigment-determining genes. This element, known as Ds, blocks the C gene and, therefore, prevents coloration of the aleurone.

In addition, there is also an element known as Ac (activator). It has control over the Ds as well as other pigment genes. It may allow the color purple at one locus and the color red at another. It may also insert at varying loci and interrupt the production of colors, thus explaining the spots and swirls that one observes in Indian corn. One of the main reasons to use "home grown" corn is that there are more possibilities for the students to observe, and they get to see greater numbers of conditions since there there is a natural control on the traits rather than a predictable one (as would be the case if corn was ordered from a biological supply company.)

The exercise is fun and very worthwhile for the student in that it truly is a genetic mystery, and they are the detectives trying to solve the problem. There will be mistakes and misleading clues, but this is fine. Students should be given more time to read through the material and ask questions when problems arise. The more they work and try different solutions, the more they will learn. It took McClintock most of her life to determine all the conditions that could exist, and this activity is only striving to make the student realize that moving genes from one area to another does happen and that there are ways that they can figure out how it has occurred.

The activity has many possibilities and options depend-

ing on teacher and student needs. It can be used for college prep students as well as advanced students, and it may also be used by individuals for a long-term project with many varieties of corn.

OBJECTIVES

At the end of this activity, students should be able to:

- Demonstrate the concept of multiple alleles and their influence on the outcome of an organism, such as corn.
- Understand that dominant and recessive genes do interact.
- Work in groups to solve the genetic mystery of Indian corn.
- Solve problems dealing with the alleles of Indian corn to demonstrate a working knowledge of the interaction of genes and their loci.
- Define transposon and describe how it affects the color of kernel corn.
- Recognize and understand the following terms: epistasis, aleurone, endosperm, locus, transposon, translocation.

MATERIALS

(Per team of 2 or 4 depending on how much corn is available. Working in pairs is preferable.)

- Genetic key of colors for corn:

R = red (dominant)
r = no color (recessive, prevents purple)

Pr = purple (dominant)
pr = no color (recessive, requires R to show color)

C = aleurone pigment (C_)
cc = no aleurone pigment
C1 = dominant to C and prevents any color in aleurone

Y_ = yellow (dominant)
yy = recessive
(remember Y and y exist only in the endosperm

- Tally sheet of your choice for students to keep data.
- Kernel key ... samples of kernels from the corn being used so that students can compare their kernels if in doubt. Simply glue each kernel possible to a piece of cardboard and place it in the front of the room for students to use.
- Two ears of corn.
- Amino acid sequence and gene assignment sheet for Part B (see last page of activity).

PROCEDURE FOR THE TEACHER

Prior to this exercise, it is recommended that the teacher review basic genetic principles and Mendelian conditions. Teachers should also review McClintock's work if they are not familiar with it, and from this, prepare a handout of some type for the students to read. The concept of multiple alleles is difficult to grasp, so the more knowledge that students have, the better. Keep handout material short and to the point and let the activity do the work. Remember, students will learn more from doing the activity than by simply reading copious amounts about it.

The handout material could contain information about B. McClintock, the role of genes in an organism, and the differences that exist in genotypes and/or phenotypes due to multiple alleles and their interactions.

Other tasks that need to be accomplished prior to doing the activity include the following:

- Arrange the pairs of corn so there is variance.
- Identify the traits for the corn for the key.
- Inform students that exact counts are not critical. They only need to understand basic ratios.
- If the class will be doing the amino acid/gene sequencing portion of the lab, then the handout for that should be discussed. Simply make these sequences up so that the students have a set in common. The point is that, if they have the gene, they can get an understanding of what DNA and RNA do in the formation of traits and proteins (pigments in this case).
- Be sure that the concept of translocation and the relationship of transposons have been reviewed. The students need to know that not all genes are stationary and that their influence can be very dramatic. The idea

that genes can move from one locus to another is a very intriguing concept. No matter what the end results of the data from the kernels and their colors are, the students will at least begin realizing how they got the many traits they have as well as an idea about why there is so much diversity in the world of biological systems.

PROCEDURE FOR THE STUDENT

The first part of this unit enables the student to determine genetic trait conditions in Indian corn due to the presence of transposons (jumping genes). Amino acid sequencing (Part B) is optional and time dependent (2-3 days).

(Handouts for students should have been distributed prior to the activity, and students should be sure they have done the reading. Students will be working in pairs.)

- Each group will obtain two ears of Indian corn from instructor.
- Each group will develop a data table to record colors and numbers of kernels on the ears of corn.
- As student groups examine the corn, the members will discuss ways that the colors may have developed. Student groups will record all colors and color variances (solid versus swirled kernels).
- Groups will next determine a ratio for each of their ears of corn (red: purple: yellow: white).
- Together, group members will determine the genotypes for the kernels. (Students should do the best work they can but should not worry if the genotypes are not totally correct.)
- Finally, groups proceed to Part B if doing the amino acid portion of this exercise. If not, students go on to the discussion questions for Part A and answer them.

QUESTIONS FOR DISCUSSION

(Make copies for the students)

1. Based on your data, what patterns, if any, do you see regarding color of the kernels? Explain.
2. What are the ratios that you obtained from the ears you and your partner had? Do they compare to what Mendel would have predicted? If the data do not correspond to Mendelian principles, how do you explain their color qualities?
3. What are two differences between dominant and recessive traits? Do the ears of corn show this condition?
4. Knowing what you do about transposons, what colors seem to be the most and least influenced? Does this support the idea of their loci on a gene?
5. Indian corn can be all one color (red, purple, blue, orange), have kernels that are swirled or spotted, and be multicolored. The corn that we eat is either yellow or white. How can this be explained through reproduction and genetic influence?

PART B ... AMINO ACID SEQUENCING (student handout)

1. In the amino acid identification portion of the exercise, student groups will be using one of the ears of corn from the first part of the exercise. The amino acid key will also be needed.
2. The students will recall that amino acids join to form proteins. The pigments found in the ears of corn are influenced by proteins. Using the key, the group will determine the theoretical amino acid for each color. Again, this is theoretical and only done to demonstrate the relationship between proteins and genes.
3. Group members will record the sequences on the data sheet with the kernel counts previously taken for each ear.
4. The ears of corn will be returned to the instructor.
5. For those who would like to test this concept, students can ask the teacher for a few kernels to plant in a garden. If the kernels grow, new ears with different colors will be produced.

HELPFUL HINTS

Teachers need to make sure that they know what transposons are and how they work. Students need to have a knowledge of DNA and RNA, transcription and translation, and the role of proteins. The teacher should also review photosynthesis. There are many applications for this exercise, and with a little creativity on the part of the teacher, the activity can be used to explain any number of genetic occurrences.

The teacher will need to make sure the students receive material about transposons and how they work. This can be obtained from textbooks and genetic publications. (A short bibliography follows.) There is a similar exercise in the biotechnology sourcebook published by the North Carolina Biotech Center and NABT (1991).

SUMMING UP

This exercise is done in the 10th grade college placement biology classes. The majority of students do very well in the exercise ... the key is not to rush them through it and not to give them all the answers. There are some levels of frustration, but this is fine. Students are trying to solve a problem that is difficult. If they have the keys available and match the letters correctly, they will get great results.

Be sure that the students were informed about transposons and how they work, as well as coloration of the kernel and where it occurs. A diagram of the embryo kernel and its parts would be helpful. Remember, the embryo stays yellow or white while the aleurone changes color.

GENE	AMINO ACID SEQUENCE (THEORETICAL)
R=RED	ACC/UGC/CCA/AUU
r=no color	CCC/GGA/AAC/AAG (prevents purple)
Pr=PURPLE	CCG/GGA/AAA/UGA
pr=no color	CCC/GCA/AAC/AAC (needs R for color)
PrR=PURPLE	CCG/UCC/CCG/UGA
prprR=RED	CCA/UGC/UGC/AAC
prprrr=no color	CCC/GGC/GGA/ACA

Each of the following must contain a C to provide color to the aleurone. Remember, too, C1 will negate coloration; thus Pr Pr RR C1C will have no color in the aleurone. An individual with cc will lack pigmentation as well. In the case of the swirled or spotted kernels, examine the original color and use that trait, keeping in mind that the Ds or Ac element inserted or blocked the process. (Ds = dissociation and Ac = activates).

Table 1. Gene representations for color with amino acid sequences. (Copies of this to go to students.)

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The Relationship of Genotype & Phenotype & the Role of Probability in Genetics

Ellen Averill
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The purpose of this lab is to familiarize students with some human traits while showing the relationship of genotype (genetic constitution) to phenotype (visible characteristics) among traits determined by both single and multiple genes and the role of probability in genetics.

OBJECTIVES

After completing this investigation, students will be able to:

- Recognize the relationship between the genotype and phenotype of an individual.
- Recognize the role of polygenic traits in phenotype expression.
- Describe the role of probability in genetics.

MATERIALS

- Unlined paper and pencils.
- Colored pencils or crayons
- Two pennies for each lab team
- One copy of directions and one data sheet per team

PROCEDURE FOR THE TEACHER

Before the lab, (1) make copies of lab directions and data tables and (2) have available unlined paper, pencils, colored pencils or crayons, and one penny per student. (Students can share colored pencils and/or crayons.)

On the day of the lab, ask students to pair off in teams of two.

PROCEDURE FOR THE STUDENT

- To determine the genotype for each trait listed, each partner will flip his/her coin. Heads will denote the gamete for a dominant trait, and tails will denote the gamete for a recessive trait.
- For the sex of the child, heads will denote the Y chromosome, and tails will denote the X chromosome. Only the father flips his coin to determine the sex of the child.
- Record the gene contributed by each parent of the data table.
- As the traits for a particular structure (i.e., eyes) are determined, draw the way the structure will look on the baby.
- Create a birth announcement or a birth certificate for the child.

HELPFUL HINTS

- Emphasize to students that some traits in humans are not determined by a single gene but are the result of many genes, polygenic traits.
- Student drawings of babies make an excellent bulletin board display.
- If time and ability permit, some students might like to make a birth certificate using a computer.
- If the lab period is more than 50 minutes or the students work quickly, the teacher might like to have them "make" a second child and compare the two children for similarities.
- Don't be surprised if some of the students want to put their children "up for adoption."

SUMMING UP

Upon completion of the lab, poll the students as to the number of dominant and recessive traits in their children. The expected 3:1 ratio for a single trait shows the frequency of dominant traits. Emphasize that many human traits are determined by polygenic inheritance rather than by a single gene. Traits caused by a single gene include freckles, widow's peak, dimples, hair texture and ear lobe. Others used in this investigation are polygenic.

Traits

Sex: Only the father flips his coin as the father determines the sex of the baby. Heads will mean that it is a boy and tails will mean it is a girl.

Face Shape:

Round (RR or Rr)

Square (rr)

Chin:

Very prominant (CC or Cc)

Less prominant (cc)

Chin shape:

Flip coin only if chin is very prominant.

Round (RR or Rr)

Square (rr)

Cleft chin:

Absent (CC or Cc)

Present (cc)

Ear size

Large (LL)

Medium (Ll)

Small (ll)

Ear lobes

Free (FF or Ff)

Attached (ff)

Hair:

Curly (CC)

Wavy (Cc)

Straight (cc)

Widow's peak:

Present (WW or Ww)

Absent (ww)

Hair color:

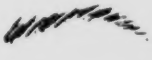
Dark hair is dominant over light. To determine the color of the baby's hair, assume ther are two genes involved and flip your coin twice to determine the two genes, HH, Hh or hh and CC, Cc or cc. Hair color is polygenic, involving more than two pairs of alleles.

Genotype	Phenotype	Genotype	Phenotype
HHCC	Black	Hhcc	Regular blond
HHCc	Black	hhCC	Dark blond
HHcc	Red	hhCc	Regular blond
HhCC	Brown	hhcc	Light blond (pale yellow)
HhCc	Brown		

Eyebrow thickness:

Bushy (BB or Bb)

Fine (bb)



Eyebrow separation:

Not connected (SS or Ss)

Connected (ss)

Eyebrow color:

Darker than hair (HH)

Same color as hair (Hh)

Lighter than hair (hh)

Eye distance apart:

Close together (EE) Average distance (Ee) Far apart (ee)

Eye Size:

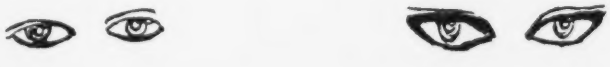
Large (LL) Medium (Ll) Small (ll)

Eye shape:

Almond or wide (AA or Aa) Round or narrow (aa)

Eye slantedness:

Horizontal slant (HH or Hh) Upward slant (hh)



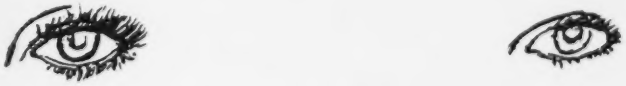
Eye color:

Dark eyes are dominant over light colored eyes. To determine the color of the baby's eyes, assume there are two gene pairs involved and flip your coin twice . The first pair of genes codes for pigment in front of the iris and the second pair of genes codes for pigment in back of the iris. Eye color is polygenic, involving more than two pairs of genes.

Genotype	Phenotype	Genotype	Phenotype
EECC	Dark Brown	Eecc	Gray-blue
EECc	Dark brown	eeCC	Green
EeCC	Brown with green flecks	eeCc	Dark blue
EEcc	Brown	eecc	Light blue
EeCc	Brown		

Eyelashes:

Long (ll or Ll) (Mm) Short (mm)

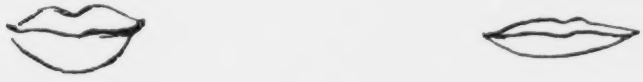


Mouth length:

Long (LL) Average (Ll) Short (ll)

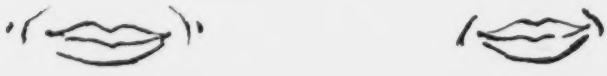
Lips:

Thick (TT or Tt) Thin (tt)



Dimples:

Present (DD or Dd) Absent (dd)

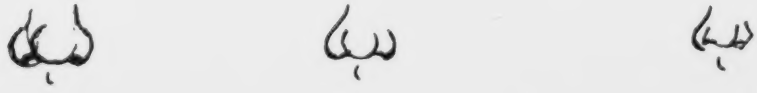


Hapsburg lip: Narrow lower jaw with a protruding underlip.

Very protruding (PP) Slightly protruding (Pp) Absent (pp)

Nose size:

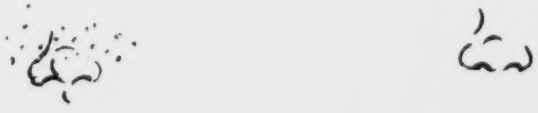
Big (NN) Medium (Nn) Small (nn)



Freckles:

Freckles present (FF or Ff) Freckles lacking(ff)

If your baby has freckles, place dots across the bridge of the nose.



Data Table

Parents' names:_____ and _____

Child's Name:_____

	GENOTYPE		PHENOTYPE
	FATHER'S GENES	MOTHER'S GENES	
Sex			
Face shape			
Chin			
Cleft chin			
Ear size			
Ear lobes			
Hair curl			
Widow's peak			
Hair color			
Eyebrow thickness			
Eyebrow separation			
Eyebrow color			
Eye distance apart			
Eye size			
Eye shape			
Eye slantedness			
Eye color			
Eyelashes			
Mouth length			
Lips			
Hapsburg lip			
Dimples			
Nose size			
Freckles			

DNA Fingerprints: Biological Barcodes

Anne B. McDonald
Lake Charles, Louisiana

This activity is designed as a very basic, simplified introduction to the concept of DNA fingerprinting to be used by students of all ability levels in grades 7-10. It is based upon the analogy between the DNA bands on an electrophoresis gel and the banding patterns on barcodes present on packaged merchandise. The focus of this activity is on how DNA fingerprints are used in identification practices by genetic counselors and forensic scientists to solve questions involving the transmission of genetic disorders, paternity, or guilt in criminal cases.

The first challenge students must undertake is to identify the different brand names of products using comparisons of the barcodes found on packaging. Then, students are shown examples of how DNA fingerprints are used in paternity or criminal cases. A comparison is made of the similarities between product barcodes and DNA fingerprints. Finally, students are given a "criminal case" entitled "The Case of the Bumped-Off Biologist" to solve by using barcodes as DNA fingerprint replacements.

When students solve the case by comparing the "biological barcodes" of the evidence left at the crime scene to the "fingerprints" of the suspects, they must submit their findings to the Judge (teacher) on an Arrest Warrant. The Judge then determines the guilt or innocence of each suspect based upon the correct matching of the fingerprints.

This activity is done as a "transition" between the factual knowledge about DNA structure and function and lab activities involving DNA gel electrophoresis. It eases student apprehension about such a complicated topic if they can have fun with the subject at the beginning of the unit.

TEACHER BACKGROUND INFORMATION

DNA is the chemical that forms genes. The human genetic pattern contains approximately 100,000 genes. These genes comprise the 23 pairs of chromosomes found in every human cell except sperm and egg cells, which carry half as many. The spiral structure of DNA is formed from four interlocking chemical subunits known as bases. Each gene is composed of 10,000 to 150,000 of these interlocking base pairs.

Ninety-nine percent of the 3 billion base pairs of human DNA are identical. DNA typing isolates the relatively few variable pairs. These regions contain short DNA sequences that are repeated in tandem a variable number of times from person to person. Although the repeat sequence, or "stuttering," remains the same in all people, the number of repetitions varies. For example, the stuttering might occur 10 times in one person and 30 times in another. When these stuttering regions are isolated out of the DNA chain, the length of the fragments varies with the number of repetitions.

In one type of genetic analysis, DNA is extracted from saliva, blood, semen, hair roots or bone. It is then snipped into fragments using enzymes that act like molecular scissors. The enzymes recognize certain sequences in the base pattern and cut the DNA molecule at those specific points. The resulting fragments are then placed on a bed of gel, and an electric current is applied. The DNA, which is negatively charged, moves through the gel toward the positive electrode. The shorter fragments move through the gel more quickly than the longer fragments and end up closer to the positive electrode.

Radioactive probes are then used to bind to any fragment containing a specific repeat sequence. The posi-

tions of these sequences are recorded as dark bands on X-ray film. Different probes can be used to identify different repeat sequences. If the positions of all the variable fragments of the sample match those from a suspect, a computer analysis calculates the probability of such a match occurring by chance.

A possible problem with DNA typing is contamination. Although research laboratories use pure DNA samples, the DNA samples encountered in forensic medicine are often hours, days or even years old. They may be contaminated with bacteria, fungi or organic material, or they may be exposed to hostile conditions such as heat and sunlight. These conditions make it difficult to extract a large enough sample to make an identification. However, it is impossible to identify the wrong person from a contaminated DNA sample, and courts have accepted such genetic evidence since it is virtually impossible to produce false results.
(from "Murder, Rape, and DNA," *NOVA Teacher's Guide*, Spring 1993).

OBJECTIVES

After this activity, students should be able to:

- Recognize that banding patterns present on the barcodes of various products are similar to banding patterns of DNA.
- Explain how DNA fingerprints are used in determining paternity, transmission of genetic disorders, or guilt in criminal cases.
- Solve a "murder mystery" by comparing "biological barcodes" of murder suspects to the "evidence" left at the scene of the crime.

MATERIALS

- Handouts of the Student Procedure
- Five colors of ditto paper (green, yellow, gold, pink, and blue or any other colors available)
- Paper cutter

PROCEDURE FOR THE TEACHER

- Duplicate copies of student procedure. (See samples at the end of this activity.)
- Duplicate each of the five evidence sheets on different colors of ditto paper. Cut each evidence sheet on the dotted lines. Retain the top section of the evidence sheet as the teacher key. (It has the name of the criminal on it and will be color-coded to match the perpetrators. Example, Gene Splicer may be printed on pink paper; therefore, he would be the guilty party to those students who receive a pink evidence slip.)
- Begin a class discussion of DNA fingerprinting by asking students if they have read about it in the newspaper or heard about it on the TV news. Have students volunteer any information they may remember.
- Pass out the Student Procedure — discuss current uses of DNA fingerprinting and the specificity of the fingerprint of each individual. Guide students through their first barcode comparison (Nestle's vs. Hershey's); then determine which characteristics the students analyzed to make their predictions (i.e., thickness, arrangement, spacing of bands, etc.). Repeat procedure with the barcode analysis of Snickers.
- Introduce examples of DNA fingerprints used in paternity testing. Compare mother/child and father/child DNA bands to establish paternity. Check for understanding.
- Review the DNA fingerprinting process used in criminal cases where crime scene evidence is compared to the DNA bands of suspects.
- Assign the murder mystery, "The Case of the Bumped-Off Biologist," for students to solve. As students read the activity, pass out one slip of colored "crime scene evidence" for each student to analyze. Vary the colored papers handed out so that each student will have a different criminal to nab. Have the students document color of their evidence and sign their names as the "Arresting Officer" on the Arrest Warrant. (Not every student will receive the same piece of evidence, so it is very important to record this information.)
- Students should compare the biological barcodes on their evidence sheet to the barcodes for each suspect in the mystery in order to solve the crime and then complete the "Arrest Warrant" to turn in to the judge (teacher).
- Evaluate student understanding of DNA fingerprint-

ing by checking the Arrest Warrant for accuracy of results. (See sample at end of activity.)

HELPFUL HINTS

- Make transparencies of the barcodes and DNA fingerprints so that students can easily refer to them during class discussion.
- Because the "murder mystery" is written in tongue-in cheek style with several references to basic genetic terminology, students should be familiar with DNA structure and function, the Human Genome Project, human genetic disorders, and Mendelian genetics.
- Laminate the colored "evidence sheets" and collect them from the students along with the Arrest Warrants. Use them again the following year.
- This activity can usually be completed in one 50-minute class period. Followup activities can then be pursued the following day.

SUMMING UP

Students have found this activity to be interesting, fun, and a welcome change of pace from the daily routine. It enables them to understand the basic concept of DNA fingerprinting without getting bogged down in the technical information about the complexities of gel electrophoresis itself. It is simple enough for the academically challenged student to follow but entertaining enough to keep the gifted students in the same class from becoming bored. It works because all students can relate to the specificity of barcodes.

EXTENSION ACTIVITIES

Some ideas for followup or extension activities include:

- Conduct a mock trial of the accused with the DNA fingerprint as court evidence. Lawyers for the prosecution and defense could research the use of DNA fingerprints in actual court cases to aid in their presentations and could detail the legal protocols necessary for DNA evidence to be used in a court of law. Classmates could play the roles of judge and jury and could base their decision of guilt or innocence on the information given during the "trial."
- Request a guest speaker from a pathology laboratory at a local hospital. Ask the speaker to bring samples of actual DNA fingerprints that have been done in the lab recently or a copy of a lab report done for proof of paternity, etc.
- Show the NOVA video "Conquest of the Killer Gene," which documents how pedigree studies and blood samples from villagers in Venezuela used for DNA fingerprinting led to the identification of the Huntington's disease gene and the subsequent development of a diagnostic test to identify the presence of the gene in individuals. For information about purchase or rental of this videotape, contact Coronet/MTI Film and Video, 108 Wilmot Road, Deerfield, IL 60015 (1-800-621-2131).
- Have students research the development of current technological advances leading to the identification of genes that cause such disorders as cystic fibrosis, Huntington's disease, sickle-cell anemia, or the recent discovery of the reverse-mutation process discovered in some cases of myotonic dystrophy, the most common adult form of muscular dystrophy.
- Contact the public health department to find out local sources of genetic counseling. Invite a genetic counselor to class to discuss how family histories and DNA fingerprinting can be used to predict the possibility of genetic disorders in offspring. Ask them to discuss the ethics involved in the decision making process couples must consider when they are planning their families.
- Obtain a DNA fingerprinting kit from a biological supply company and perform a DNA gel electrophoresis in your classroom, using your own apparatus and power supply.
- Show the NOVA video, "Murder, Rape, and DNA," aired March 2, 1993, which reviews various applications for DNA fingerprinting and the pros and cons of this type of genetic analysis. It also compares two typing methods currently used in DNA fingerprinting. For information about purchase or rental of this videotape, contact WGBH Collection, P.O. Box 2053, Princeton, NJ 08543 (1-800-828-WGBH).
- Refer to the *National Geographic* article, "DNA Profiling: The New Science Identity" (May 1992). Use the section titled "One Family's Fingerprints" to show how

inheritance of a particular genotype occurs through three generations in a family. Use the graphics in the section titled "To Make a DNA Print" to construct a bulletin board showing the laboratory procedures involved in making a DNA fingerprint. Use the remaining sections of this article to show the wide array of uses for DNA fingerprinting in today's society: solving crimes; identifying potential organ donors; studying ancestral heritage, migration, and behavior patterns in archaeological finds; documenting identities of kidnapped children; and learning about breeding patterns in endangered species.

• Offer recreational reading for students related to DNA and DNA fingerprinting:

Cook, R. (1993). *Blindsight.* New York: Berkley Books.

Cook, R. (1988). *Mortal Fear.* New York: Putnam's Sons.

Crichton, M. (1990). *Jurassic Park.* New York: Ballantine Books.

Wambaugh, J. (1989). *The Blooding.* New York: Bantam Books.

REFERENCES

Beardsley, T. (1992, July). "DNA Fingerprinting Reconsidered (Again)," *Scientific American.*

Canzano, C. (1990). "DNA Fingerprinting." *A Sourcebook of Biotechnology Activities.* Richmond, VA: National Association of Biology Teachers, North Carolina Biotechnology Center.

Franklin-Barbajosa. (1992, May). "DNA Profiling: The New Science Identity," *National Geographic.*

Keehn, J. (1992, March 15). "The Long Arm of the Gene," *American Way Magazine.*

Krajick, K. (1993, January 11). "Genetics in the Courtroom," *Newsweek.*

"Murder, Rape, and DNA." *(1993, Spring). NOVA Teacher's Guide.* Boston, MA: WGBH.

Zonderman, J. (1990). *Beyond the Crime Lab.* New York: John Wiley and Sons.

TEACHER'S COPY:

Run off this EVIDENCE SHEET, cut on the dotted lines, and distribute to your students as they read "The Case of the Bumped Off Biologist".

#########The criminal is PROFESSOR DEAN AYE!!!###########

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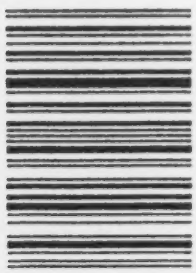

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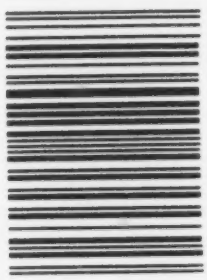

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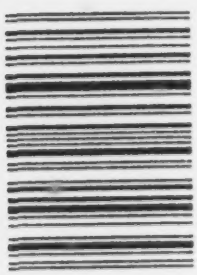

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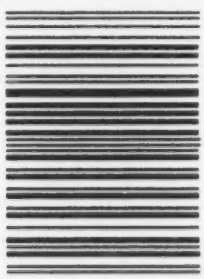

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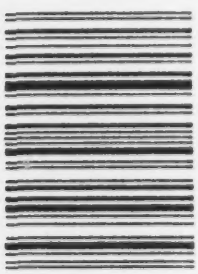

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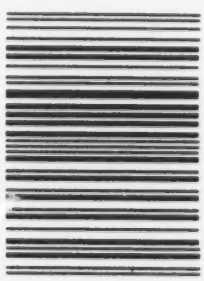
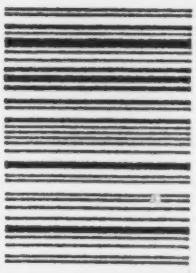


Alternate Teacher Evidence Sheet #1:
THE CASE OF THE BUMPED OFF BIOLOGIST
CRIMINAL #1 = GENE SPLICER

CRIMINAL



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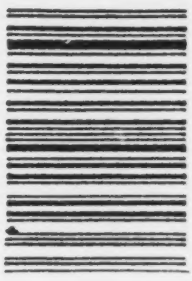

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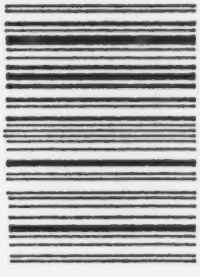

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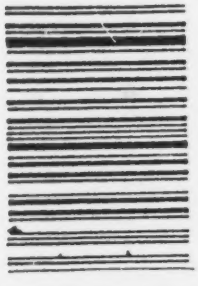

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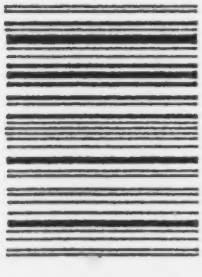

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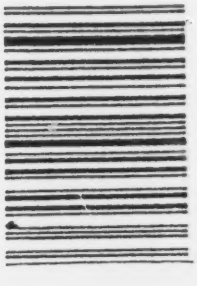
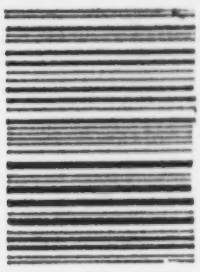


Alternate Teacher Evidence Sheet #2:
THE CASE OF THE BUMPED OFF BIOLOGIST
CRIMINAL #2 = COLONEL PURP. L. CORN

CRIMINAL



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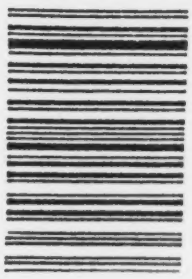

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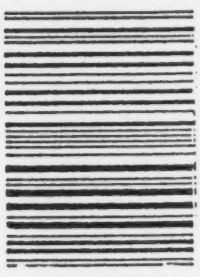

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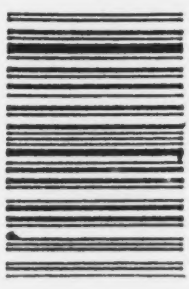

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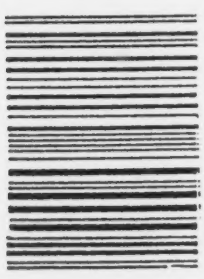

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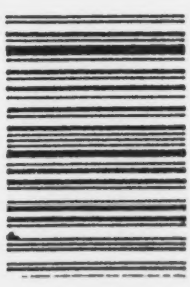
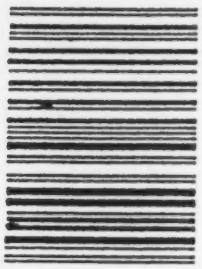


Alternate Teacher Evidence Sheet #3:
THE CASE OF THE BUMPED OFF BIOLOGIST
CRIMINAL #3 = JILL FOR-REESES

CRIMINAL



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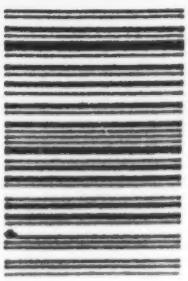

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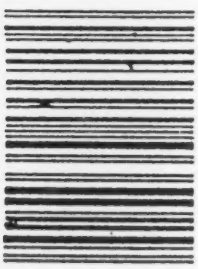

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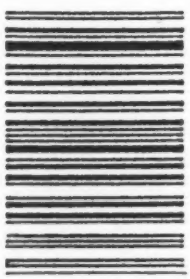

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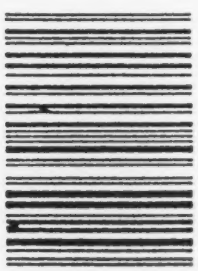

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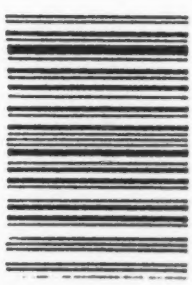
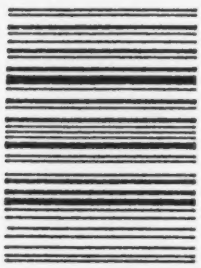


Alternate Teacher Evidence Sheet #4:
THE CASE OF THE BUMPED OFF BIOLOGIST
CRIMINAL #4 = MEW THANT

CRIMINAL



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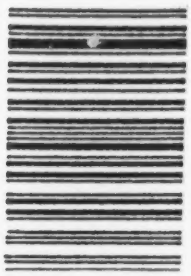

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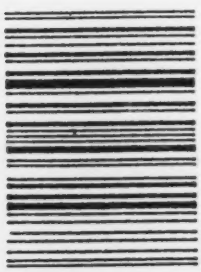

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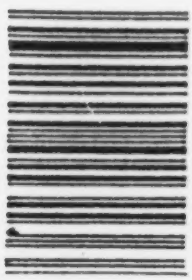

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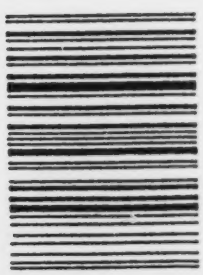

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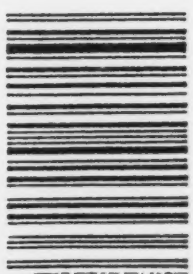


DNA FINGERPRINTS: BIOLOGICAL BARCODES

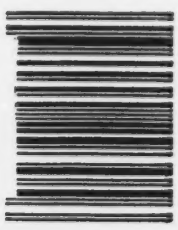
DNA FINGERPRINTING is the latest technology being used to identify the source of human DNA in paternity cases, diagnosis and treatment of genetic diseases, and in criminal cases. The military is currently setting up a DNA databank to ensure identification of any personnel that may otherwise become "Unknown Soldiers" in any future combat situations, and over 16 states are developing similar databanks documenting the convicted felons in their prisons. Some hospitals record the DNA FINGERPRINTS of all newborns in case they will someday be needed for the identification of missing children, genetic links to disease, or as an identification source for potential organ donors. Sources of DNA samples include not only blood but also skin, semen or hair roots which can be used in forensic cases. In rare instances, DNA can also be extracted from bones.

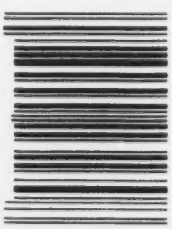
Large pieces of DNA are the same in every human because each of us has the same body components: hair, eyes, arms, legs, a heart, etc. But a few sections of human DNA vary from person to person -- it is these parts of the DNA which makes each of us unique. Because no two individuals (except identical twins) have genetic patterns that match exactly, DNA FINGERPRINTS can be used much like regular fingerprints as a method of specific identification for every person on Earth.

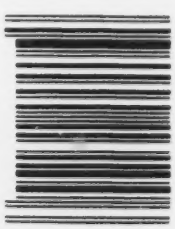
A DNA FINGERPRINT consists of bands that occur on developed X-ray film after a very lengthy, complex, and technical laboratory procedure called *gel electrophoresis*. To the novice, these bands resemble a **bar code** -- a series of stripes often found on grocery products or packaged merchandise. The bands on a bar code are specific for the manufacturer and the individual product that is being sold.

PROCEDURE:

Look at the barcodes below. They represent NESTLE'S CRUNCH, HERSHEY'S KISSES, and HERSHEY'S MR. GOODBAR products. Circle the barcode that represents NESTLE'S CRUNCH.







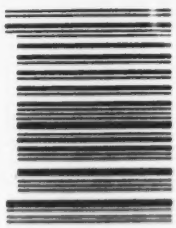
What specific characteristics about the barcodes did you analyze before making your decision?

_____

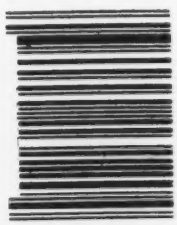
_____

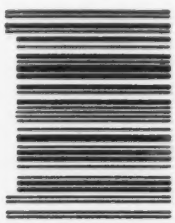
_____

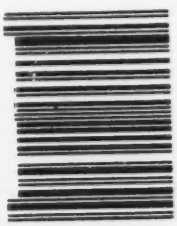
Look at the barcode below. It is from a SNICKERS bar, a product of the M+M/Mars company.

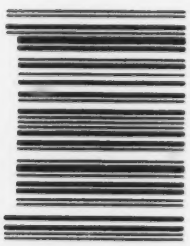


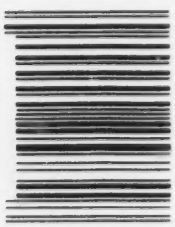
Which of the following barcodes represents a bag of M+M's? Circle your answer.

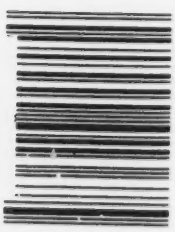


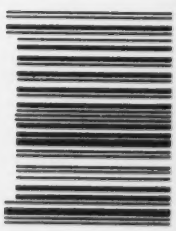








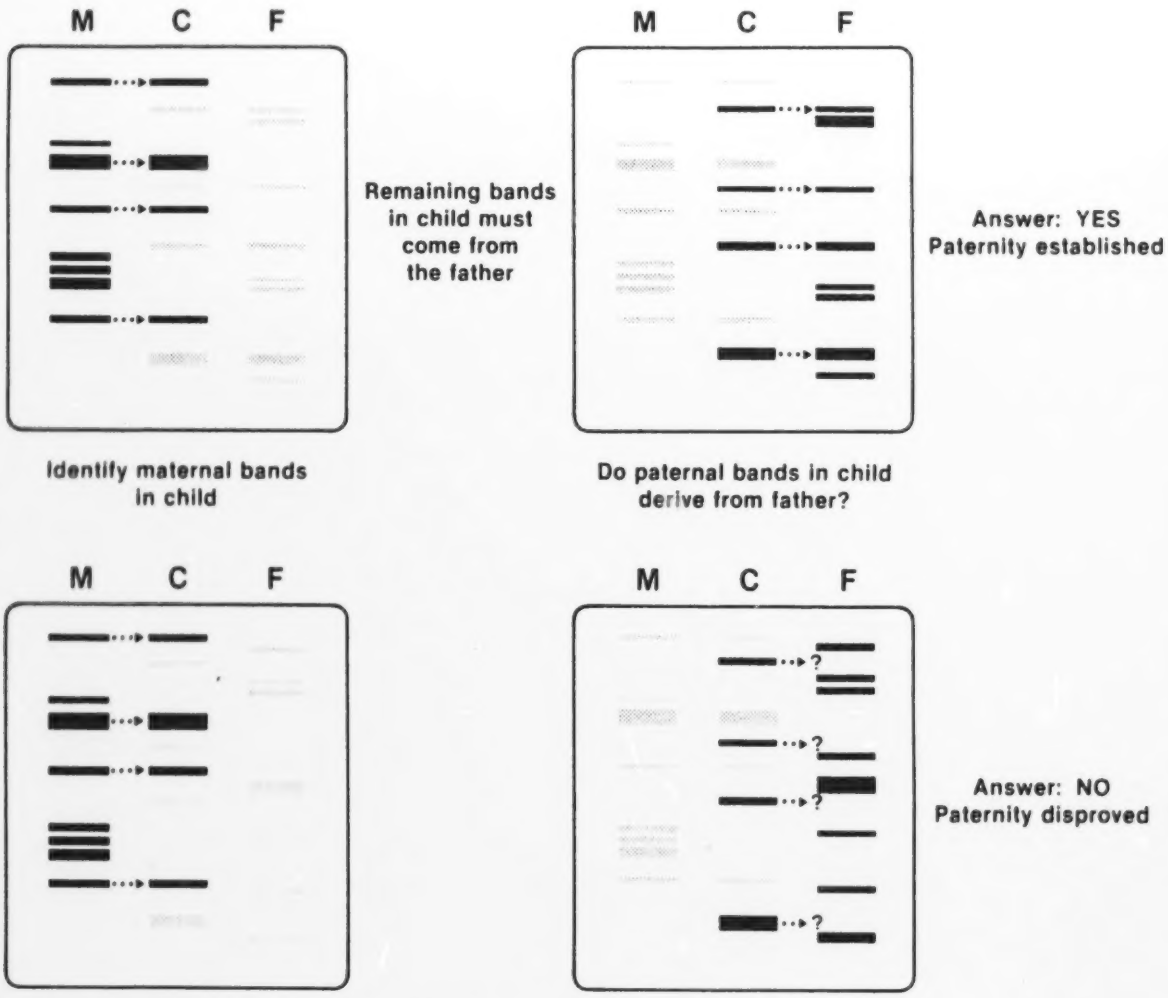




Paternity cases can be proven by taking samples of the mother's blood, the child's blood, and the questionable father's blood. DNA FINGERPRINTS are produced. The bands that the mother and child have in common are identified first, then, the remaining bands of the child are compared to the "father's" bands. If the child's bands and the "father's" bands MATCH, then the man's paternity is proven. If the bands DO NOT MATCH, then the man is NOT THE FATHER OF THE CHILD.

EXAMPLE:

Analysis of DNA Fingerprints in Paternity Testing


M C F
Identify maternal bands in child
Remaining bands in child must come from the father
M C F
Do paternal bands in child derive from father?
Answer: YES Paternity established
M C F
M C F
Answer: NO Paternity disproved

*Diagrams courtesy of CELLMARK Diagnostics.

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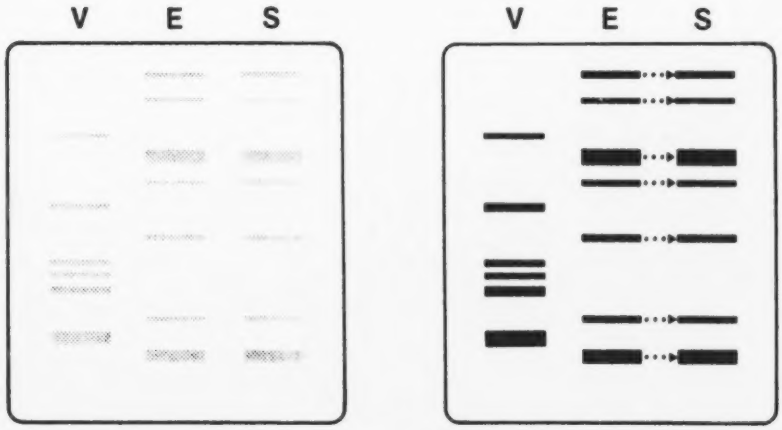
In criminal cases, the DNA FINGERPRINTS of the victim, biological evidence left at the crime scene, and the suspect would be compared. If there is a match in band patterns between the suspect and the sample found at the crime scene, this can be used in a court of law to prove the guilt of the suspect.

Example:

ANALYSIS OF DNA FINGERPRINTS IN FORENSIC TESTING

Answer:

NO MATCH



Answer:

MATCH

LEGEND

V = Victim

E = Evidence

S = Suspect

*Diagrams courtesy of CELLMARK Diagnostics.

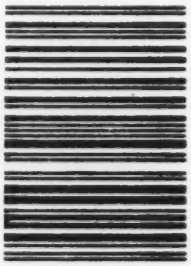
BIOLOGICAL BARCODES:
THE CASE OF THE BUMPED-OFF BIOLOGIST

You are a forensic expert assigned to the state crime lab. Your specialty is using modern biotechnology to solve the unsolvable -- so called "perfect crimes!" Today you are sent to investigate the murder of Mr. Ded Boddy, the victim of a stabbing. Mr. Boddy was found on the floor of a research lab at the university where he was a student in Molecular Biology. The coroner's office has been unable to link any of the clues to the suspects, so they're depending on your keen eye and expertise to find the guilty party. The suspects who have been questioned in this case are:

JILL (aka "ELECTRO") FOR-REESES: girlfriend of the deceased. (whenever anyone fooled with her peanut-butter cups, her temper would flash like lightning!)

MUG SHOT

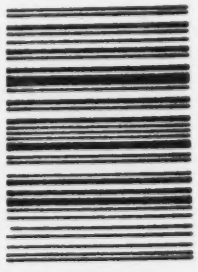
DNA FINGERPRINT



MEW THANT: easily recognized by his recessive hairline. A physical education major who roomed with Ded, MEW was dubbed "el Helix" for his classic spiral passes on the football field (not to mention the "passes" he made at Jill whenever Ded wasn't around!).

MUG SHOT

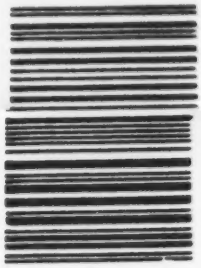
DNA FINGERPRINT



COLONEL PURP L. KORN: commander of Ded's ROTC platoon. (became "popping mad" during drill when Ded called him DOMINANT behind his back!)

MUG SHOT

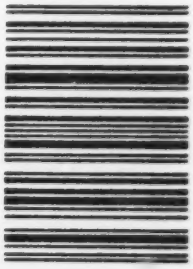
DNA FINGERPRINT



PROFESSOR DEAN AYE: paranoid scientist with a totally twisted outlook on life (suspected Ded of substituting barcodes from candy bars for his research data on the genetics of the Hershey family of Pennsylvania.)

MUG SHOT

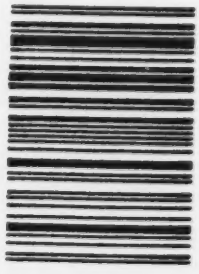
DNA FINGERPRINT



GENE SPLICER: Auntie Codonna's favorite nephew and Jill's hairdresser. (Ded's friend, Jimmy WATSON, saw Gene lovingly massage a CRICK out of Jill's neck during her last appointment. (when Ded found out, he had Gene restricted from cutting hair and filed a complaint to the Beauty Shop Ethics Committee, who then revoked his license.)

MUG SHOT

DNA FINGERPRINT



After reading the coroner's report of the autopsy, you find one item that had been overlooked by the investigators -- Ded had apparently scratched his murderer and had remnants of skin and hair under his fingernails! BINGO !!!!! You take out your trusty DNA test kit and get to work. It takes four days of exhausting work, but you finally get a DNA fingerprint of the criminal. Just to be on the safe side, you also take a tissue sample of Ded himself to use as a comparison. Now all you have to do is compare the DNA fingerprints of each suspect to those of the criminal in order to crack the case!

PROCEDURE:

1. Obtain a set of evidence collected at the crime scene from your teacher.
2. Record the color of your evidence sheet on your ARREST WARRANT and sign your name as the "arresting officer."
3. Compare the DNA fingerprints of the suspects to those of the criminal.
4. Complete the ARREST WARRANT and submit it to the JUDGE (your teacher) along with the evidence.

ARREST WARRANT

I HEREBY ARREST_____
FOR THE MURDER OF DED BODDY, BASED UPON THE EVIDENCE OF DNA FINGERPRINTING, PROVIDED TO THE COURTS FOR PROSECUTION.

_____
signature of ARRESTING OFFICER.

DEFINE:

DNA fingerprinting:

forensic science:

WHAT IS THE OBJECTIVE OF THIS ACTIVITY?

WHAT SOURCES OF DNA SAMPLES CAN CURRENTLY BE USED IN FORENSIC CASES?

WHAT EVIDENCE DID YOU ANALYZE WHEN COMPARING DNA FINGERPRINTS?

IF YOU WERE A JUROR IN A MURDER TRIAL THAT USED DNA FINGERPRINTING, WOULD THE EVIDENCE CONVINCE YOU OF THE GUILT OF THE DEFENDANT? WHY OR WHY NOT?

Use of DNA Fingerprinting in Forensic Science

Nancy Howard
Brookline, Massachusetts

This activity is used to demonstrate the use of restriction enzymes and electrophoresis in making DNA fingerprints for the positive identification of a person.

OBJECTIVES

- The students will learn how restriction enzymes cut DNA molecules at specific base sequences and produce DNA fragments of varying lengths.
- The students will learn how electrophoresis separates different-sized fragments of DNA and how these separated fragments can then form a recognizable pattern.
- The students will learn the principles behind the use of DNA fingerprinting for the identification of people.

MATERIALS

Pencils and/or pens of two different colors.

PROCEDURE FOR THE TEACHER

The teacher should have the students divided into groups, so the work can be shared.

PROCEDURE FOR THE STUDENT

Purpose – The purpose of this exercise is to learn about a simplified form of DNA fingerprinting that can be used for the positive identification of a criminal.

A. The Crime

Late one night, the famous rock star, Rockina, returned to her luxurious apartment from an appearance at a concert. As she entered her locked apartment, she noticed that everything in her apartment was a mess — the drawers had been emptied out onto the floor; the cushions on the couch were ripped open; and the safe behind the picture on the wall had been opened. She then noticed that the lights were on in her bedroom.

She stormed into the bedroom and surprised a burglar in the process of removing her magnificent (and expensive) jewelry from its hiding place beneath the mattress. Indignant, she jumped on the burglar and tried to stab the person with her nail file. While she was able to inflict a small wound, she was no match for the assailant's knife. In the subsequent struggle, she was killed, and the murderer escaped with her jewelry.

B. The Investigation

When the housekeeper, Casparina, entered her apartment the next day, she saw the body and immediately called the police. When they noted that there had been no signs of a forced entry, the investigation narrowed down to people who knew Rockina and who had a key to enable them to enter her apartment. The suspects were:

1. Casparina, the housekeeper, who had just had a bitter argument with Rockina over a refused raise in salary.
2. Lucifer, her former boyfriend, who she had just jilted for another man.
3. Pinky, the leader of her weight lifting class, who was her new boyfriend. It was rumored that Pinky was insanely jealous of Rockina's fame.

When it was established that all three of the suspects had a key to Rockina's apartment, all had a motive for killing her, and all had no ironclad alibi for the evening that she was killed, the police realized they had a problem. They consequently decided to hire a world-famous forensic science team to use DNA fingerprinting to prove which of the suspects was guilty of Rockina's murder.

C. Use of Restriction Enzymes

As the lesson progresses, students will see how forensic scientists make DNA fingerprints from DNA found in sperm cells, blood or other human cells. They make use of a type of enzyme called "restriction endonucleases" or, more commonly, "restriction enzymes."

When these enzymes recognize a certain area of a DNA molecule (a specific order of bases), they cut the DNA at that point. However, when they cut the DNA, they do so unevenly, making it a jagged cut.

For example, the restriction enzyme EcoRI cuts DNA at the following base sequence:

G|AATTC
CTTAA|G

So, if this enzyme were used on the following segment of DNA,

TTACGTA|GAATTCCCTTAGAGATG|AATTCCCTTA
AATGCATCTTAAGGGAATCTCTACTTAAGGGAAT

it would be cut in the following manner:

TTACGTAG AATTCCCTTAGAGATG AATTCCCTTA
AATGCATCTTAA GGGAATCTCTACTTAA GGGAAT

Use of this enzyme on the above segment of DNA would then yield three different-sized fragments.

Each restriction enzyme only cuts at one particular sequence of bases. To see how these fragments are made and used:

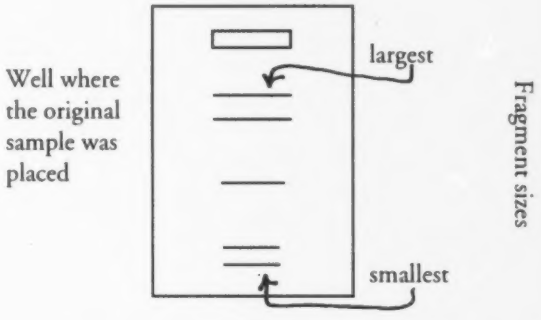
1. Obtain sheets showing the same portion of DNA from each of the suspects and the DNA from the sample of blood taken from Rockina's nail file.

2. Divide into two teams. One team is to analyze the DNA using the restriction enzyme called HindIII; the other is to use the restriction enzyme EcoRI. To do this, (a) look for the sequences of bases that the group recognizes and mark, right on the sheet, where it will cut and (b) count the bases that will be in one strand of that fragment (use the top strand of the fragment) and put that number above that fragment.

Recognition sequences:
G|AATTC (EcoRI)
CTTAA|G

A|AGCTT (HindIII)
TTCGA|A

3. Use of Gel Electrophoresis – After the restriction enzymes have cut the DNA, the fragments in each sample are then separated by size by a technique called "gel electrophoresis." In this technique, each sample is put into a well (a hole going part way into the material) in a block of agarose. (This is similar to a block of a highly purified "Jello®-like" substance.) An electric current is passed through the agarose, which then pulls the smaller fragments through the block faster than the larger ones. The fragments will end up as lines sorted by size.



To see how the electrophoresis creates the fingerprint of the suspect's DNA fragments, estimate the location of the bands in the agarose gel after electrophoresis. Draw the bands on the gel, labeled for the enzyme used. (The band above was used as a reference; it has DNA with fragments 5, 10, 15, 20, 25 and 30 bases long. Use that to estimate the location of the fragments in the DNA.) Put the electrophoresis results of both teams on the same sheet. Each team is to check the location of the bands of the other team's fragments for accuracy.

4. What do the HindIII results show? What do the EcoRI results show?

5. To do the most accurate analysis possible (as forensic scientists, you want to be able to prove who killed Rockina), repeat the procedure using both enzymes together.

• Using red pen (or some color other than what was used before), mark the cutting sites of both enzymes on each suspect's DNA. (Divide the work among members of your group.)

• Above each fragment, write the number of bases in that fragment. (Again, use the top strand.)

• Mark the bands that are obtained from electrophoresis on the agarose gel on the bottom of the "Gel Electrophoresis" page.

6. Who murdered Rockina?

QUESTIONS FOR DISCUSSION

1. Explain why the scientists used a combination of restriction enzymes rather than just one.

2. Suppose that the lab technician did a poor job of making the agarose gels. The material was not dissolved well in the water when making the gel. As a consequence, the agarose has pockets of more dense material interspersed in a less dense background. Explain how this might affect the results of the electrophoresis.

3. What would happen if the restriction enzymes were damaged somehow and didn't work? How would you recognize this on the gel? Explain how it would look and why it would look that way.

FURTHER INVESTIGATIONS

• This method of using electrophoresis for separating DNA fragments is the basis for procedures used in areas other than forensic science. For instance, it is the basis of one of the procedures for identifying genetic diseases in fetuses and for determining which people are carriers of certain genetic diseases.

Suppose that this is the DNA making up a normal gene for a certain trait:

CGGAATTCGTAAATCCGGCATGAATTCCGGGAGAATTCCG
GCCTTAAGCATTTAGGCCGTACTTAAGGCCCTCTTAAGCC

If this were cut by EcoRI, what size fragments would be produced? Draw the appearance of the gel obtained after electrophoresis.

Where in this DNA molecule could a mutation occur (where one base changed to another) to cause a difference in the fragment sizes caused by the cutting of the restriction enzyme EcoRI? Indicate one place where this mutation could be. (There are a number of possibilities.) Next, figure out the size of the fragments that would result from the mutant gene and then draw the gel. If this mutation caused a particular genetic disease, then the different appearance of the gel would be able to be used to diagnose it.

A carrier is a person who is normal for a trait but has a mutant gene and can pass it to his or her offspring. If a person has one normal DNA and the mutant DNA that was produced above, what would the gel look like that would be produced from his/her cells? (Remember that people have two genes for each trait.)

• How similar do fingerprints have to be in order to be used as identification? Research how fingerprints are characterized and used for positive identification.

• Research what other methods, in addition to DNA analysis and fingerprint identification, are used in forensic science.

• Arrange for a visit to a nearby forensic science laboratory.

PORTIONS OF JUNK DNA

(See "Junk DNA" diagrams at the end of this activity.)

The actual procedure of DNA fingerprinting is a bit more complicated and uses a technique called "Southern blotting" (because it was first developed by Edward Southern).

1. The DNA is obtained from the crime scene (sperm cells, blood cells, skin scrapings from under the fingernails, etc., or other cellular material) and from suspects.

2. Each sample is cut into fragments by one or more restriction enzymes.
3. The fragments from each sample are put into a well on a block of agarose gel, which is then electrophoresed. This will separate the DNA fragments by size, the smallest moving the greater distance.
4. The fragments are then treated in such a way as to cause the DNA molecules to come apart and form single strands without moving from their positions.
5. They are then transferred (affixed in their positions) by being blotted onto a nylon membrane.
6. This nylon membrane (again, with the fragments in single strands in their "sorted" positions according to size) is then exposed to molecules of radioactive DNA that have certain base sequences (called "DNA probes"). These probes are single stranded and will bond to the DNA fragments wherever they find a complementary series of nucleotides. In this case, they will bind to specific sequences of a portion of the "junk" DNA in the fragments. (To identify one person from another, scientists use pieces of "junk DNA," which is a section of human chromosomes that is highly variable form one person to another — with the exception of identical twins. It is called "junk DNA" because it does not code for proteins and has no known function.)
7. The nylon membrane is now placed on a piece of X-ray film. Only the fragments of junk DNA which have the radioactive probe attached will expose the film, showing the locations of only those fragments. The resulting pattern of fragments on the film will be different from one individual to another and can thereby be used to identify that person.

HELPFUL HINTS

• The students should already be familiar with DNA structure and the concept of base complementarity. They should also have some idea of what enzymes do.
• This activity can be used to introduce the topics of restriction enzymes and the use of electrophoresis to separate different size DNA fragments, or it can be used to reinforce those topics when taught first by the teacher.
• This activity is an excellent introduction to the actual electrophoresis of DNA fragments done in the laboratory.
• An excellent article on the identification of criminals is "DNA Fingerprinting: New Witness for the Prosecution" in *Discover Magazine* (June 1988). Have the students read it either before or after this activity.
• This activity can lead to discussions on the use and ethics of DNA fingerprinting for the identification of criminals, paternity and maternity suits, etc. The United States Army is now planning on using this method to identify any service men and women killed in action. They apparently are taking a cell sample of all personnel in the Army and are saving it to be used to identify any unknown bodies, in the hopes of never again having any "unknown soldiers." (Older methods of identifying dead bodies relied to a certain extent on dental records. Young Americans have so many fewer fillings that this has become unreliable.)
• The use of DNA fingerprinting for identification purposes is still somewhat controversial. The laboratories doing the work must be meticulous in following the correct procedures, as sloppy lab work has caused this type of evidence to be thrown out of court in at least one trial. It has, however, been successfully used in other cases.
• Note that, in order for this procedure to be used, the criminal must leave some DNA behind. This generally means cellular material (sperm cells in the case of a rape, blood, skin scraping under the fingernails of the victim, roots attached to hair that has been pulled out, etc.)

(See Answer Keys for Use of Enzymes at the end of this activity.)

Answers to the Discussion Questions

1. Using a combination of enzymes will produce a wider variety of different-sized pieces to be sure to produce a different pattern in the gel for each person.
2. If the agarose was of uneven consistency, then the different-sized fragments would not move through it to the same extent. Pieces would move more slowly through a more dense area and more quickly through a less dense area, making the comparison of one person's

gel pattern to that of the DNA left at the crime scene unreliable.

3. If the enzymes were damaged, then they wouldn't cut the DNA into smaller pieces. Only one band on the gel would be obtained, and it would be near the well, as it would be large enough not to travel far.

Answers to Further Investigation

Cutting of the DNA that is given will produce fragments of 3, 19, 11 and 7 bases long. The gel will then have these four bands. A mutation in any of the three recognition sequences of EcoRI will eliminate one of these cuts; for instance, changing the 4th base from an A to a G will eliminate the first cut in the DNA molecule. Upon using the enzyme, only two cuts will be obtained, getting fragments of 22, 11 and 7 bases. This would give a different appearance on the gel. A change in any of the other two places where the EcoRI cuts would produce an elimination of that site, again giving a larger fragment than the normal gene has. A carrier would have both the normal gene and the mutant gene, so he or she would have both the four fragments of the normal DNA and the three fragments of the mutant DNA. The gel would show five bands; in the example given, bands of 22, 19, 11, 7 and 3 bases (in that order on the gel) would be apparent.

SUMMING UP

This activity illustrates the use of restriction enzymes in identifying a criminal from a group of suspects. The DNA was cut into fragments, and those fragments were separated by electrophoresis. The pattern of fragments was then matched to the DNA left at the scene of the crime and positively identified one of the suspects (Pinky) as having the same pattern.

Portions of Junk DNA - Student Handout

FROM THE NAIL FILE

TTGAGAATTCAAGCTTCCGATGGAATTCGAAATCAGAAGCTTATAGAATTCGCGCTAAGCTTCCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTAGTCTTCGAATATCTTAAGCGCGATTCGAAGGGCCTTAAGCAAGGTAT

FROM CASPERINA'S DNA

TTGAGTATTCAAGCTTCCGATGGAATTCGAGAATTCAAGCTTATAGAATTCGCGCTAAGCTTCCCCGGAATTCGTTCCATA
AACTCATAAGTTCGAAGGCTACCTTAAGCTCTTAAGTTCGAATATCTTAAGCGCGATTCGAAGGGCCTTAAGCAAGGTAT

FROM PINKY'S DNA

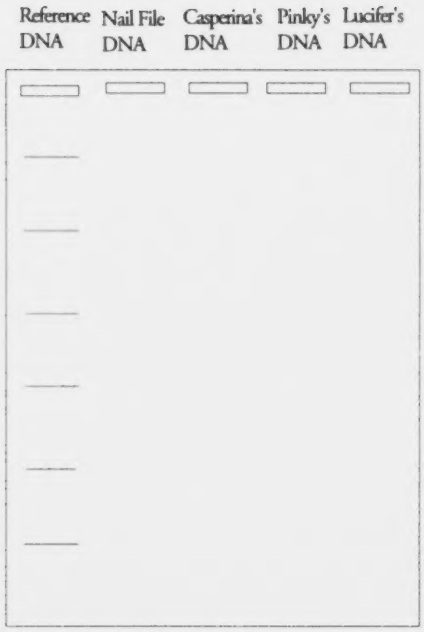
TTGAGAATTCAAGCTTCCGATGGAATTCGAAATCAGAAGCTTATAGAATTCGCGCTAAGCTTCCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTAGTCTTCGAATATCTTAAGCGCGATTCGAAGGGCCTTAAGCAAGGTAT

FROM LUCIFER'S DNA

TTGAGAATTCAAGCTTCCGATGGAATTCGAAGCTTGATCGTTATAGAATTCGCGCTAAGCTTCCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTCGAACTAGCAATATCTTAAGCGCGATTCGAAGGGCCTTAAGCAAGGTAT

EcoRI Gel

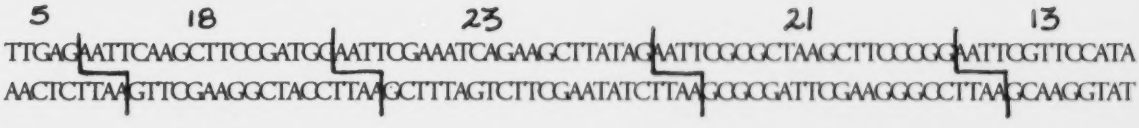
HindIII Gel



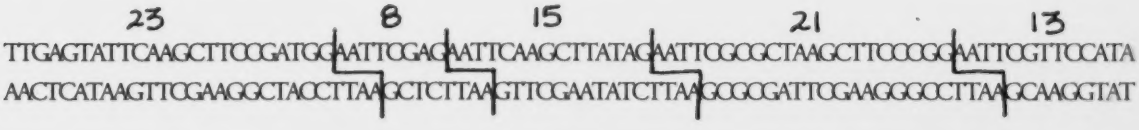
Both Enzymes Gel

Portions of Junk DNA - Answer Key for Use of EcoRI

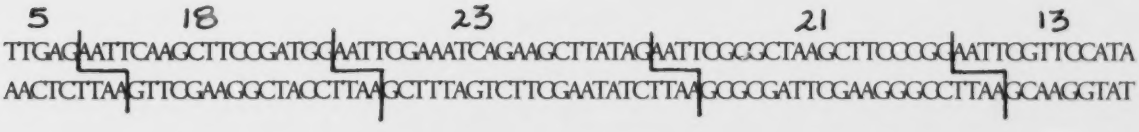
FROM THE NAIL FILE



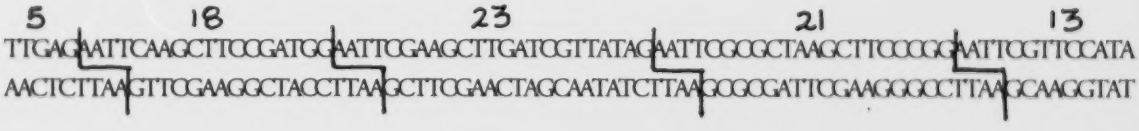
FROM CASPERINA'S DNA



FROM PINKY'S DNA

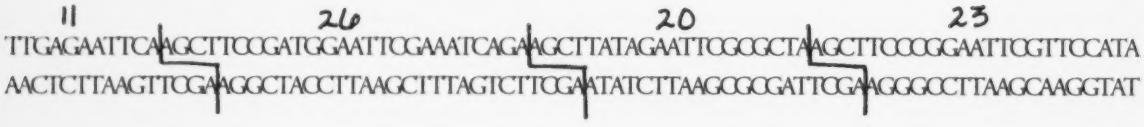


FROM LUCIFER'S DNA

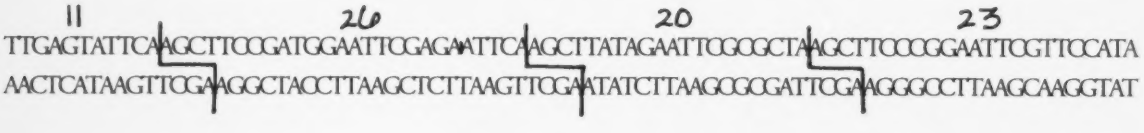


Portions of Junk DNA Answer Key for Use of HindIII

FROM THE NAIL FILE

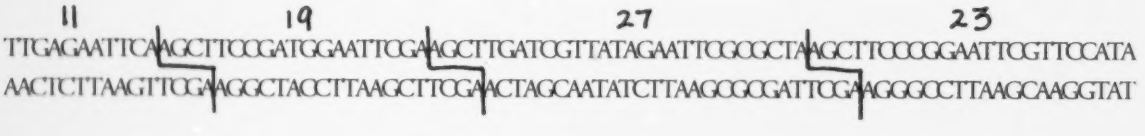


FROM CASPERINA'S DNA



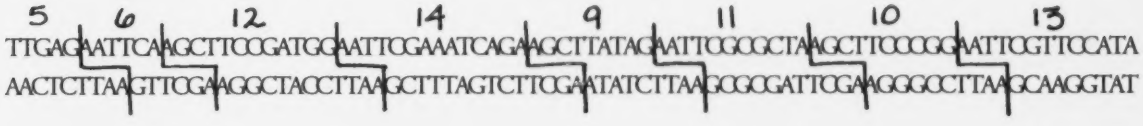
FROM PINKY'S DNA

FROM LUCIFER'S DNA



Portions of Junk DNA - Answer Key for Use of Both Enzymes

FROM THE NAIL FILE



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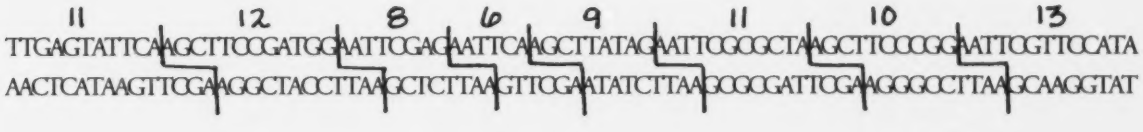

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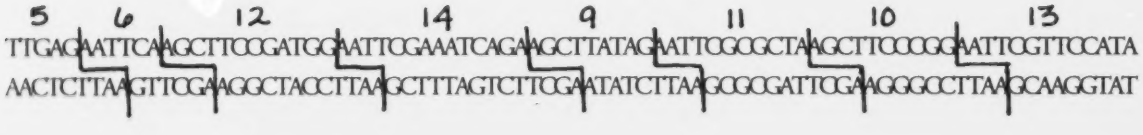

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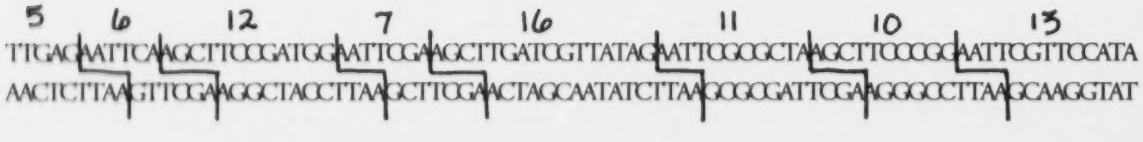
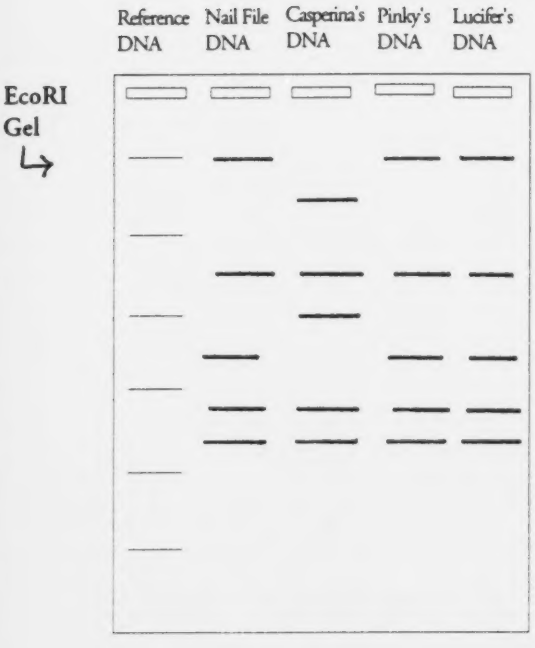
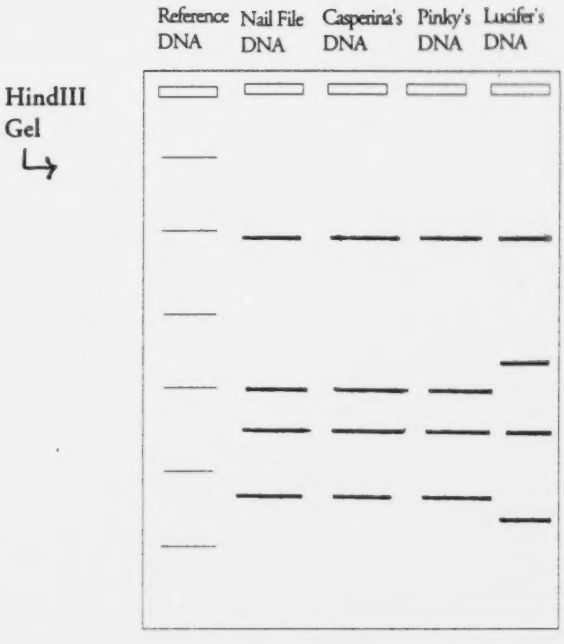
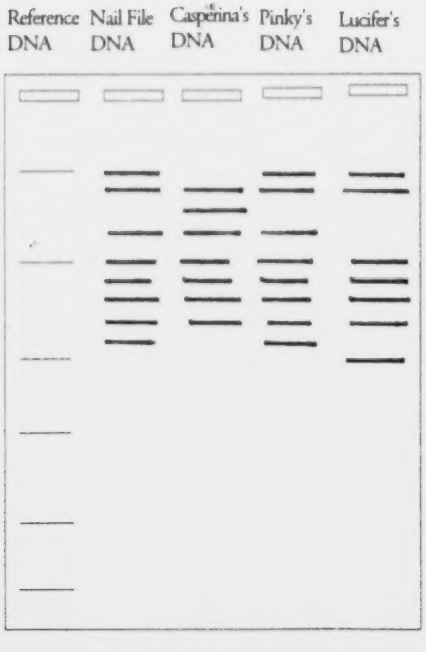








Both Enzymes Gel

Answer Key to Gels

Section III - Variation & Diversity of Life

Fibonacci Numbers & Biological Patterns

Richard F. Clevenstine
Springfield, Pennsylvania

"Fibonacci Numbers and Biological Patterns" is a set of laboratory exercises that provides students with experiences in which they can explore the interrelationships between mathematical sequences and common patterns of anatomical structure in plants and animals. This laboratory set of experiences was developed to enrich available high school biology programs, particularly in units concerning patterns of growth and development. Individual lesson plans or the entire series of lab investigations may be used to supplement any introductory biology program.

Students are initially presented instruction on the history of Fibonacci and Fibonacci mathematical patterns, using either a conjecture of rabbit reproduction patterns or a real biological example of bee ancestry. The Fibonacci sequence of numbers (1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, etc.) was first proposed by Leonardo of Pisa in the year 1228 A.D. in Liber Abaci or the "Book of the Abacus."

Subsequent lessons include in-field studies of plant phyllotaxis and phyllotaxic ratios with inquiry into plant survival; observational studies of spiraling arrangements in pinecones, artichokes or pineapples; observational studies of sunflower and daisy flower petal displays; in-field studies focusing on "Fibonacci branching patterns;" pedigree studies of the genealogy of the bee; the construction of an equiangular spiral and its implications in studying the chambered nautilus; and/or an observational laboratory experience into the study of regular pentagons and echinoderm body plans.

OBJECTIVES

- Students explain what is meant by a Fibonacci sequence and discuss the logical progression of its number order.
- Students explain and demonstrate natural occurrences of Fibonacci sequences in the natural world.
- Students discuss beneficial adaptive strategies or consequences of organisms that have Fibonacci sequences.

MATERIALS

The room used in this program was a laboratory-based classroom or the outdoors. Materials needed for these activities include:

- Pinecones
- Artichokes
- Pineapples
- Sunflowers
- Chambered nautilus shells
- Starfish
- Sand dollars
- Sea urchins

Teachers implementing this program or sections of this program should use the following reference: Garland, T.H. (1987). *Fascinating Fibonaccis – Mystery and Magic in Numbers.* Palo Alto, CA: Dale Seymour Publications. (Phone: 415/ 324-2800)

Lesson #1 or Day #1 of the Lab

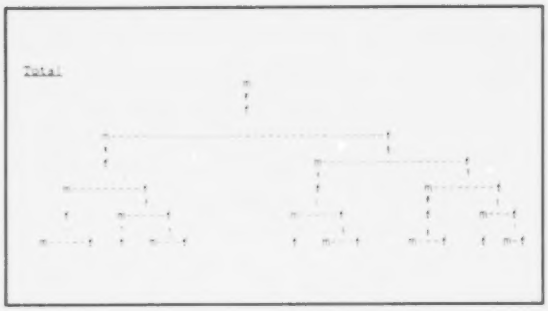
PROCEDURE FOR THE TEACHER

Discuss with the students the origins and definitions of the Fibonacci sequence and how this aspect of mathematics integrates with the biological sciences. After establishing the conceptual basis of the lesson, use either the classical bee or the hypothetical rabbit problem, or both, to come up with the sequence of numbers 1, 1, 2, 3, 5, 8, 13, 21, 34, 55 ...

The Bee

This is a true story. The male bee hatches from an unfertilized egg. The female bee has both a mother and a father. So, we may look at the ancestry of the male bee

in this way:



The Rabbit

This is a story of conjecture. Suppose that there is one pair of rabbits in a field at the beginning of month 1. This pair will breed another pair of rabbits at the beginning of month 3. The new pair of rabbits will begin to breed when they are two months old. Every pair will give birth to a new pair of rabbits EVERY MONTH, beginning at two months.

Question – How many pairs of rabbits will there be after 12 months?

Month	Newborn Pairs	Old Pair	Total Pairs
1	1	0	1
2	0	1	1
3	1	1	2
4	1	2	3
5	2	3	5
6	3	5	8
7	5	8	13
8	8	13	21
9	13	21	34
10	21	34	55

Work out the sequence to 20 or so places. Talk about the primary pattern — that any number is the sum of the two preceding numbers — and discuss how this pattern arises from the bee or rabbit problem.

Discuss whether these scenarios really occur in nature. Why or why not? If so, what would be some of the consequences?

Lesson #2 or Day #2 of the Lab

PROCEDURE FOR THE TEACHER

Fibonacci Numbers can be used to explain phyllotaxis and growth patterns of plant stems. "Phyllotaxis" is the study of the arrangement of leaves on a stem and their relationship to one another. This can be either an outdoor or indoor exercise.

Students can determine phyllotactic ratios or stem spiraling in the following manner: "On a plant, locate a stem directly above another stem and count the number of full circle turns the branch makes while producing new stems in between as well as the newest stem." (The original stem is not counted.) (Garland 1987, p. 7)

If, for example, a plant has a phyllotactic ratio of 8/11, a student might interpret that it took eight complete turns of a branch to generate 11 stems. Examples of phyllotactic ratios are provided in *The 1977 Yearbook of Science and the Future* (p. 189). Provide students with examples either in the classroom setting or outdoors. Set up examples. Have available different fruits, vegetables, and flowers, as described below:

PROCEDURE FOR THE STUDENT

Part A – Using tree branches provided by the teacher or using trees outdoors, Fibonacci numbers can also be used to explain the branching pattern of some plants. Some branch and root systems come very close to displaying the "Fibonacci branching pattern."

In order to determine the branching pattern, locate the initial stem that branches into two on the plant. Follow these branches and observe that one branch should divide and one will not. This should repeat as the branches form new successive layers up the plant. Each new successive divide should approximate a Fibonacci number. What is the Fibonacci sequence observed? Is there any adaptive function to this sequence? Explain.

Part B – The growth and development patterns of certain plant structure, such as pinecones, pineapples, artichokes and flower petals, can be predicted using the Fibonacci sequence.

Pinecone: If you count the number of spirals in either direction, you get Fibonacci numbers. Also, mark one scale on the cone. Now find the scale where these two spirals meet again. Count the number of scales between these two intersections — it should be a Fibonacci number. Look for two patterns — one parallel and one steep. Patterns include 3/5, 5/8, 8/13.

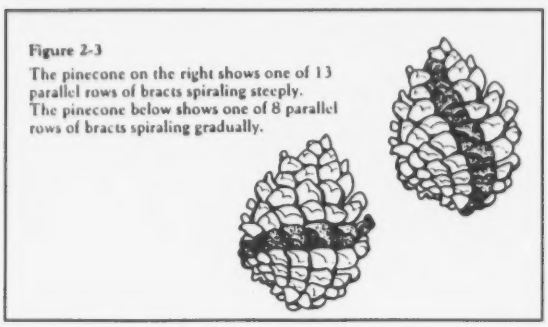


Figure 2-3
The pinecone on the right shows one of 13 parallel rows of bracts spiraling steeply. The pinecone below shows one of 8 parallel rows of bracts spiraling gradually.

Artichoke: The outer petals of artichokes are positioned in the same way that the scales of the pinecone are arranged. There are two sets of patterns: one gradual and one steep. These patterns are usually in a 3/5 or 5/8 pattern.

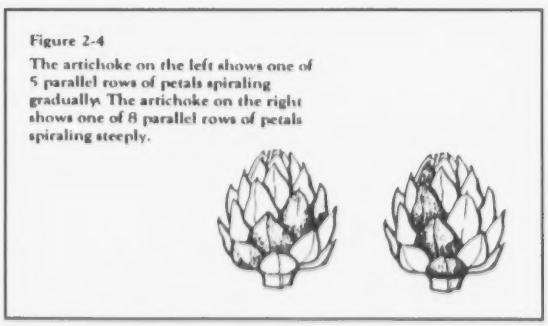


Figure 2-4
The artichoke on the left shows one of 5 parallel rows of petals spiraling gradually. The artichoke on the right shows one of 8 parallel rows of petals spiraling steeply.

Pineapple: Examine pineapples and discover that there are three patterns of rows of hexagonal scales. These patterns include gradual, medium and steep parallel spiral rows. Discover the Fibonacci pattern.

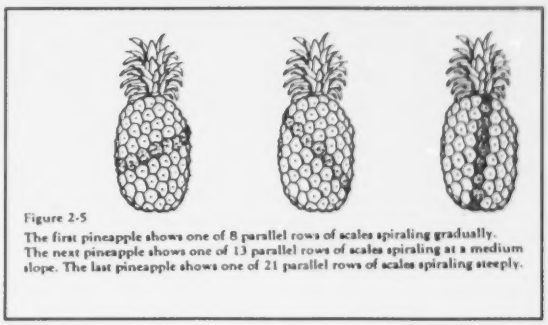


Figure 2-5
The first pineapple shows one of 8 parallel rows of scales spiraling gradually. The next pineapple shows one of 13 parallel rows of scales spiraling at a medium slope. The last pineapple shows one of 21 parallel rows of scales spiraling steeply.

Flower: Count the petals on these flowers and find the Fibonacci numbers.

- Iris, lily, primrose, buttercup (3 petals)
- Columbines (5 petals)
- Dahlia, ragwort, mayweed, asters, chicory (8 petals)
- Double delphiniums, globe flower (13 petals)

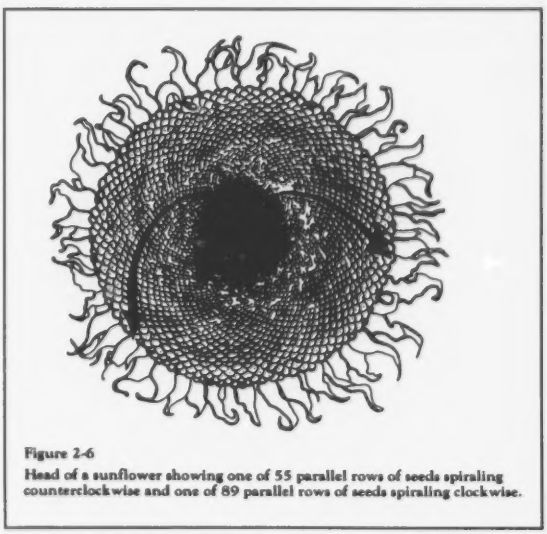


Figure 2-6
Head of a sunflower showing one of 55 parallel rows of seeds spiraling counterclockwise and one of 89 parallel rows of seeds spiraling clockwise.

- Marigold, field daisy, gaillardias (21 petals)
- Hawkweeds (34 petals)
- Daisies (55 petals)
- Michaelmas daisies (89 petals)

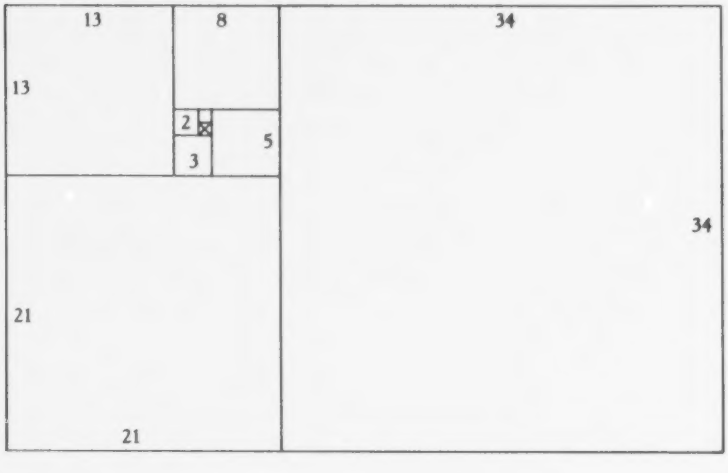
Using sunflowers, count the number of spirals on the face of the flower. There will be 34 one way, 55 the other; or 21 and 34; or 55 and 89.

Lesson #3 or Day #3 of the Lab

PROCEDURE FOR THE TEACHER

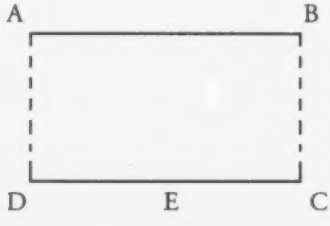
Discuss the pattern of growth of the chambered nautilus and certain echinoderms, using the geometry of Fibonacci numbers. In order for students to understand the construction of the chambered nautilus shell, they first must understand the reasoning behind the construction of an equiangular spiral. Garland (1987, p. 14) explains the construction of an equiangular spiral as follows:

1. Make a one-unit square.
2. Add another one-unit square to the first square.
3. Add a two-unit square to the structure.
4. Add a three-unit square to this structure.
5. In a similar way, add aquares of 5, 8, 13, 21, 34 units, etc.



After completing the construction of the squares, quarter-circle arcs should be drawn for each square. Quarter-circle arcs can be constructed as follows:

- *Step 1* – Label a square ABCD and let E be the midpoint of DC.
- Using EC as a radius, construct an arc-circle that intersects line BC.



Connect the quarter circles of all squares sequentially, and an approximation of an equiangular spiral similar to that of the chambered nautilus shell has been constructed.

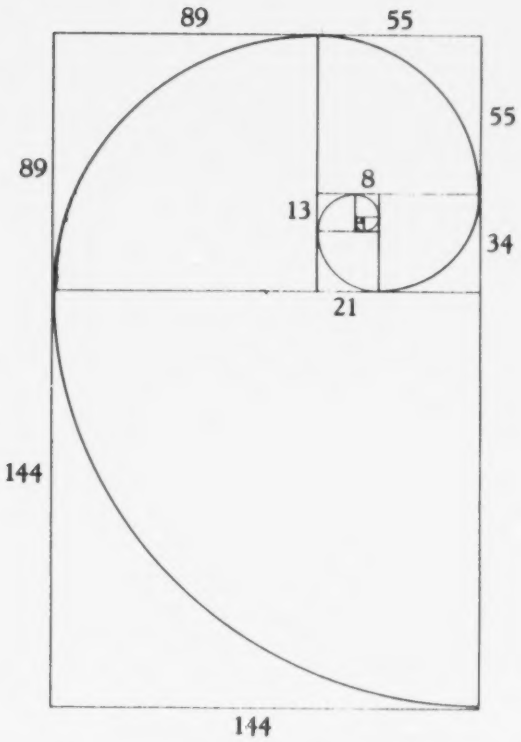
PROCEDURE FOR THE STUDENT

Question – How does the equiangular spiral allow for accommodation of growth and the contour of the body of the chambered nautilus? How does an increase in the shell radii and the intersections of the radii allow for uniformity of size and increased living space for the body of the animal?

Further study – Study the equiangular patterns of a spider's web, a bacterial growth curve, or the horn of a wild sheep.

ECHINODERMS

The students will study examples of pentagons in flowers, echinoderm starfish and sand dollars. "The proportions of a pentagon approximate the proportions between adjacent Fibonacci numbers; the higher the numbers are the, more exact the approximation becomes. For example, if the measure of the side of a pentagon is a Fibonacci

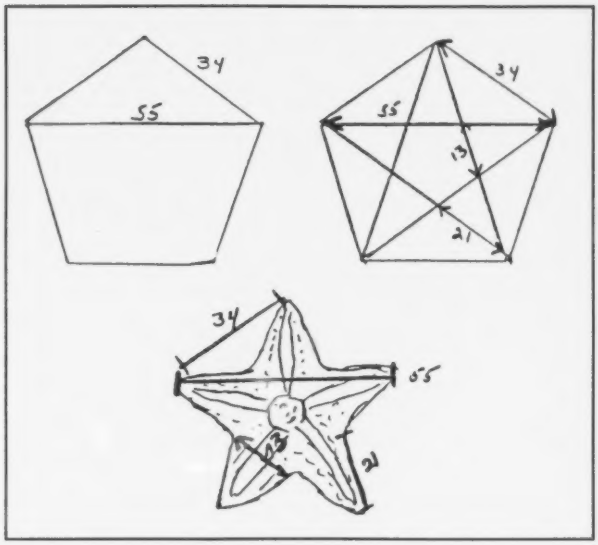


number, the measure of its diagonal is the next Fibonacci number in the sequence. Furthermore, the diagonals of any such pentagon separate each other into two adjacent Fibonacci numbers." (Garland 1987, pp. 17-18).

Determine the Fibonacci sequence of a typical starfish, sand dollar, brittle star, conch shell and snail shell.

HELPFUL HINTS

This lesson works really well if the teacher reviews the cited references prior to doing this lab. Collect and evaluate all specimens for Fibonacci sequences prior to doing this activity.



SUMMING UP

The study of mathematical relationships and their occurrences are relevant to the study of biological systems. As written, this lab is primarily an introductory exercise that should engage the curiosity of the student about the geometry of life. However, this lab exercise could act as a springboard for further advanced study, particularly with reference to the golden triangle, golden rectangle, or equiangular spiral, in studying common bird eggs, leaf shapes, growing ferns, sea shells, light and angular reflection, bee hive cells, and/or human proportion.

REFERENCES

Garland, T.H. (1987). *Fascinating Fibonaccis – Mystery and Magic in Numbers.* Palo Alto, CA: Dale Seymour Publications.

1977 Yearbook of Science and the Future. (1976). Chicago, IL: Encyclopedia Britannica.

Vertebrate Skeletons & Adaptation

Jim Morrill
Lakeville, Connecticut

The skeleton, the framework of an animal's body, gives shape, support and protection. In some animals, like worms, the skeleton is created by internal fluid under pressure (hydrostatic). In insects, the skeleton is a hardened outer covering which forms an external shell (exoskeleton). For vertebrates, the skeleton is an internal bony structure (endoskeleton). In these animals, the skeleton serves as a place for muscles to attach, bringing about skeletal, and hence, body movement. The skull portion of the vertebrate skeleton commonly includes special structures like teeth that make it easier to eat different types of food. The skeleton is the result of evolutionary change and, therefore, adapts the animal to its environment and way of life.

OBJECTIVE

The objective of this lab is to understand adaptation by relating structure to function. Students will study a variety of vertebrate skeletons and mammal skulls.

In Part A, class members will observe whole skeletons to answer questions about locomotion. Part B introduces mammal skulls and allows students to become familiar with adaptations related to diet. Part C presents a number of unknown mammal skulls. Using the information gained from Part B, students will analyze the characteristics of an unknown skull and hypothesize whether or not the organism is an herbivore, carnivore or omnivore.

MATERIALS

Part A – Purchase prepared skeletons from biological supply houses, or you and your students can prepare them from purchased carcasses.

Parts B and C – Order the mammalian skulls from general supply houses or from Skulls Unlimited (P.O. Box 6741, Moore, OK 73153). You can also prepare skulls from purchased carcasses.

PROCEDURE FOR THE TEACHER

The lab is easy to set up. Arrange the lab like a "lab practical" with stations spread out around the laboratory or classroom. Each station contains a different, clearly-defined whole skeleton or skull. Grouping students in pairs, or threes, works best since grouping promotes discussion. If possible, provide several specimens at each station, so more than one group can work there at one time. Even with multiple specimens, the groups usually have to start the lab at different stations to prevent bottlenecks.

Parts A and B can be done in any order. Part C, however, should only be done after the first two parts are completed. Using the lab's "Procedure: Students" sheets, the students progress at their own pace from station to station. For the unknown skulls, use as many omnivores as possible since they present interesting combinations of herbivore and carnivore dentition.

PROCEDURE FOR THE STUDENT

(See Student Procedure pages at the end of this activity.)

HELPFUL HINTS

If done in its entirety, this lab requires two or more hours, depending on the sophistication of the students. In addition to the time given to the student to work with the specimens, the teacher needs to introduce each section by providing background information. For example, use a human skull to discuss the concept of a dental formula before starting Parts B and C.

However, do not give too much information. The students must answer the questions in the exercise, using their own powers of observation and not directly

from the information given in the teacher's introductory remarks. It is a good idea to circulate constantly during the lab, providing background information and helping the students come to the point where they can answer the questions themselves. If the skulls are missing teeth and bones, extra information may need to be provided.

The lab does not have to be done in its entirety. Parts B and C, "Mammalian Skulls" and "Unknown Skulls," stand by themselves and can probably be completed in a double lab period, again depending on how fast the students work.

It is not difficult to prepare vertebrate skeletons and skulls from carcasses provided by supply houses. I have had particular success using dermestid beetles from Connecticut Valley Biological Supply (Valley Road, P.O. Box 326, Southampton, MA 01073).

Norman McComb, Connecticut Valley's chief bone technician, is particularly helpful and can be readily reached by calling 1-800-628-7757. Mr. McComb has also written a small, but complete, pamphlet entitled *Preparing Skeletons Using Dermestid Beetles,* which not only describes how the beetles are used but carries the skeletal project through the degreasing, bleaching and mounting phases.

SUMMING UP

Students enjoy this lab. They seem to have a natural fascination with skulls and skeletons, and yet they very rarely get to study them in school. This activity can also be used as an introduction to the evolution taught in the classroom. It is helpful to have students understand something about adaptation at a tangible level before gene pools and gene frequencies are discussed. Most importantly, the lab teaches the value of careful observation and seeing relationships using real material.

REFERENCES

Abramoff, P. & Thomson, R.G. (1972). *Laboratory Outlines in Biology.* California: W.H. Freeman and Company, Ex. 36 and 6A.

Hickman, C.P. & Hickman, C.P. Jr., F.M. (1974). *Integrated Principles of Zoology.* St. Louis, MO: The C.V. Mosby Company, Ch. 23-26.

Radinsky, L.B. (1987). *Evolution of Vertebrate Design.* Chicago,IL: University of Chicago Press, p. 171.

PROCEDURE: STUDENTS

Part A: SKELETONS AND LOCOMOTION

Following the directions of your teacher, move from specimen to specimen at your own pace reading the appropriate section of the lab and answering the questions in the spaces provided, or in your notebook.

1. Fish Skeleton:

Examine the fish skeleton and notice the pair of pectoral, or chest fins, and further down the body, the pair of pelvic fins

Observe that all of the bones that make up the backbone of the fish are pretty much to same. There is no special structure of the backbone for holding the fins.

How do you account for the lack of special structures of the backbone for holding the fins?

2. Amphibians: Mud Puppy and Frog Skeletons:

The majority of vertebrates have two pairs of appendages with each pair supported by a girdle. The appendages and girdles have the same basic structure. There are, however, modifications which represent adaptations to different environments and ways of life.

Observe the mud puppy skeleton. What is the similarity between the backbone of the fish and the backbone of the mud puppy?

What is the position of the limbs in the mud puppy in relation to the trunk of the body? (lateral, ventral, or dorsal)

Observe the frog. Note its backbone. How does it differ from that in the mud puppy?

Look at the pelvic girdle of the frog. Notice that it is larger and more substantial than the one found in the mud puppy. Relate the frog's backbone and pelvic girdle structure to its mode of locomotion.

Which of these two amphibians--the mud puppy or the frog--is closest in structure to the fish? Explain your answer.

3. Reptile and Mammal Skeletons: a comparison of the skeletons of crocodile and cat.

Examine the legs of each skeleton. Which one has the longer appendages in proportion to the length of the body?

For each specimen, what is the position of the legs in relation to the trunk of the body (lateral, ventral, dorsal)
crocodile:
cat:

Notice that the bones that make up the backbone in the crocodile interlock loosely allowing the backbone to move from side to side. In the cat backbone, however, the bones so tightly interlock that very little lateral movement is allowed.

Using your observations of the length and position of the legs and the nature of the backbones, compare walking in the crocodile to that in the cat, and determine which mode of locomotion is better for traveling on land.

Part B: MAMMALIAN SKULLS

Mammalian skulls show differences in overall shape, size of the cheekbones, and numbers and types of teeth. These differences are often due to differences in diet and ways of procuring food. A dental formula is used for classifying the teeth of a mammal. The formula gives the number and type of teeth for half of the upper jaw and half of the lower jaw starting in the front of the mouth. For example, the human dental formula is:
upper jaw---2 incisors, 1 canine, 2 premolars, 3 molars
lower jaw---2 incisors, 1 canine, 2 premolars, 3 molars

Herbivore:

Beaver Skull: The dental formula of the beaver is typical of rodents:
upper jaw--1 incisor, 0 canines, 0 premolars, 5 molars
lower jaw--1 incisor, 0 canines, 0 premolars, 5 molars

Find these teeth in the beaver skull. Notice how the tips of the incisors are shaped like chisels.

Find the gap between the incisors and molars. This gap, called a diastema, is commonly found in herbivores and marks the location of the missing canines and premolars.

Work the jaws of the beaver skulls and notice that the lower jaw has considerable freedom to move from side to side.

In mammals, the cheekbone serves as a place of attachment for jaw muscles. Notice that the cheekbone in the beaver is relatively large in comparison to the skull size. A large cheekbone accommodates a large mass of jaw muscle and indicates a strong bite.

Deer Skull: Try to determine the dental formula of the deer skull by filling in the numbers in front of the tooth types:

upper jaw	___Incisor	___Canines	___Premolars	___Molars
lower jaw	___Incisor	___Canines	___Premolars	___Molars

What are the similarities between the teeth and jaws in the deer and the beaver that are related to eating plants?

In contrast to the beaver, notice that the cheekbone in the deer is small in comparison to the size of the skull. How do you account for this difference?

Carnivores:

Cat Skull

Examine the teeth of a cat skull and determine its dental formula:

upper jaw
lower jaw

Notice the very large canine teeth and how both the incisors and canines are sharply pointed.

Observe the premolars and molars. Describe what they are like:

Are the premolars and molars capable of chewing and grinding food, or do they cut and tear? Explain your answer.

Observe that the lower jaw joins with the skull in such a way that allows only up-and-down motion but almost no side-to-side motion.

Notice how large the cheekbone is in comparison to the overall size of the skull.

Using your observations of the skull and teeth, explain how a carnivore eats its food:

Part D: UNKNOWN SKULLS

After you have completed Parts A and B, move to the numbered stations that have the unknown skulls. Use the chart titled "UNKNOWN SKULLS" and starting with any station you like, fill in the specimen number, skull characteristics, including size of cheekbone, dental formula, and other characteristics. Finally, describe what the unknown eats (carnivore, herbivore, omnivore) and give evidence of your choice.

UNKNOWN SKULLS

Specimen Number	Size of Cheekbone in Relation to Skull Size	Dental Formula	What Animal Eats: Herbivore, Carnivore, or Omnivore, & Why

Section IV - Life Processes

Probing Through Photosynthesis in Aquarium Plants

Cheryl Gardiner Callahan
Savannah, Georgia

Green plants, including those in aquariums, carry out respiration, photosynthesis and transpiration. Respiration produces carbon dioxide, and carbon dioxide is necessary for photosynthesis. One of the end products of photosynthesis, oxygen, is also necessary for respiration to occur.

As photosynthesis occurs throughout daylight hours, carbon dioxide is used, and pH rises slightly (increase in OH-). After daylight hours, carbon dioxides is no longer used at as high a rate, as light and dark reactions slow and ultimately stop.

Respiration, however, continues, and the respiration rate is greater than the photosynthetic rate, which causes the pH of aquarium water to begin to drop. At dawn, an increase in light reactions will increase dark reactions, also increasing the rate of carbon dioxide use, and the aquarium water pH should rise again.

OBJECTIVES

In this investigation, the student will be able to:

- Measure the pH of an aquarium plant community over a period of time.
- Relate the change in pH to the amount of carbon dioxide present.
- Relate the change in pH to the process of photosynthesis.

GRADE LEVEL

Grades 10-12

MATERIALS

- Computer with pH probe interface
- Leafy aquarium plants (e.g., Elodea – the younger the plants the better), 5-6 sprigs/computer setup
- Aquarium or pond water, pH 7 to 9
- 400 ml beaker
- Distilled water
- Buffer of known pH (for probe calibration)

PROCEDURE FOR THE TEACHER

- Probe should be thoroughly rinsed with distilled water prior to placing ANY substance for which you want a pH reading.
- If natural light is not available, plant lights will suffice, but it will be necessary to vary the distance of the light from the plants throughout the day and to turn lights off to simulate diurnal changes.
- Measurements should be taken over one period of daylight and dark hours; 24 hours gives a nice diurnal cycle.
- If the computer software graphs data as it takes measurements, the teacher may want to designate the Y axis to plot only from pH 5 to pH 12. Changes are easier to note.
- pH probes are very sensitive and need to be recalibrated each time they are used. Follow the directions for the interface system when recalibrating probes.

PROCEDURE FOR THE STUDENT

- Set up computer pH probe interface according to computer/interface instructions.
- Set the computer program to take measurements approximately every 10 minutes for 24 hours (144 measurements).
- Using only about 10 cm of the tips of the aquarium plants, place 5 or 6 sprigs in a beaker with approximately 300 ml of aquarium water.
- Calibrate the pH probe as directed by the interface system.
- Rinse the pH probe in distilled water. Secure the probe in the beaker of aquarium plants and set near a window so as to receive good light. (Be certain to stir the water with the pH probe before securing it to the side

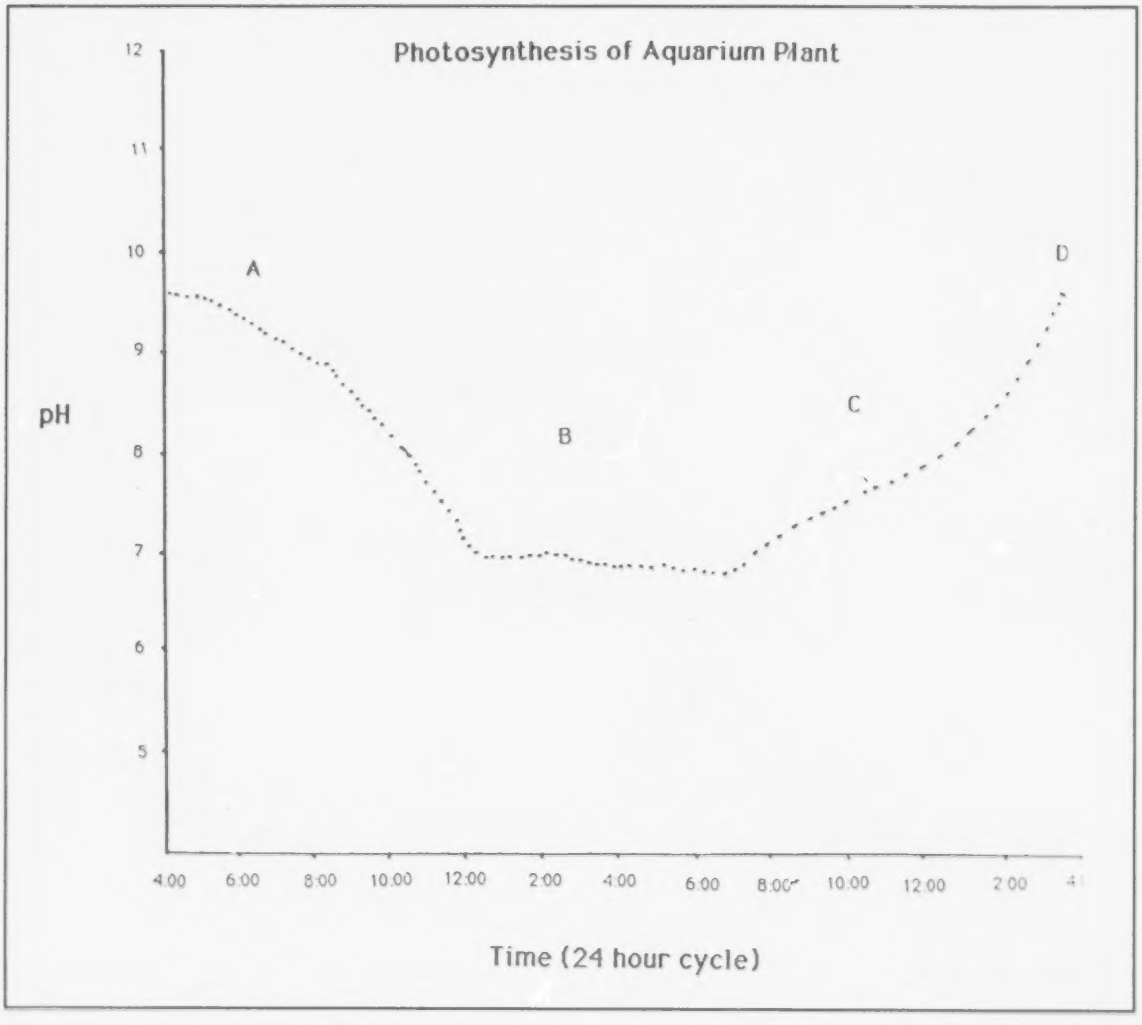
of the beaker.)
• Begin taking measurements.
• Note weather conditions throughout the day, particularly cloud cover and storms.

ANALYSIS AND INTERPRETATION

1. Graph pH vs. time. Plotting every third point is sufficient. Time increments of 30 minutes will be sufficient. (See sample graph below.)
2. During what time of day was photosynthesis occurring at the greatest rate? How can one tell?
3. What could account for the dropping of pH during daylight hours?
4. In a separate paragraph, provide a conclusion to this exercise using the following concepts: photosynthesis, cellular respiration, light, and the production, usage, and concentrations of carbon dioxide.

FOR FURTHER STUDY

• Repeat for other species of aquarium plants.



• While taking measurements, also collect oxygen released by one of the plants by placing a test tube over (upside down) the plant. Compare the amount of oxygen collected to the carbon dioxide being used (refer to graph). Can any correlation be made? Explain.
• Repeat using a light source other than natural light, such as fluorescent light, plant light, or colored (green, red, blue) light.
• Repeat using altered environmental temperatures (add ice; place beaker on low heat).

Answers to Questions on Page 81:
1. (See graph of photosynthesis below.)
2. Students should describe a time of the day when the slope is the greatest and positive.
3. Cloud cover; rainy period; sun being blocked (as by placing a black cloth or aluminum foil over the experimental plants).
4. The plant continues to undergo respiration, producing carbon dioxide, and therefore lowering pH. Students should give an overview of photosynthesis, both light and dark reactions.

DATA:

Begin Time: _____ AM or PM

Time	pH	Time	pH	Time	pH	Time	pH	Time	pH

Fermentation Laboratory: All Living Organisms Need Food

Karen Nisimoto
Kaneohe, Hawaii

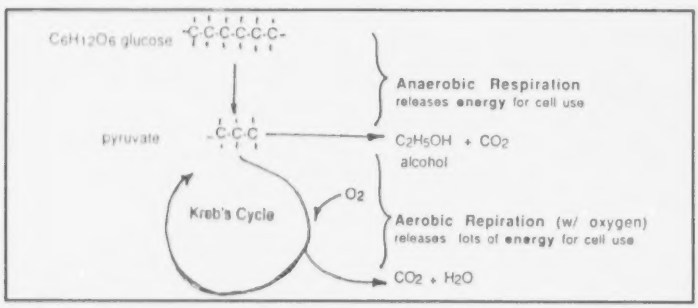
All organisms need food energy. According to the Second Law of Thermodynamics, a system, such as an organism, must continuously take in energy to preserve organization; otherwise, the system will go to entropy (randomness, fall apart, die, etc.). Through photosynthesis, plants are able to convert light energy into the chemical bond energy of food (glucose) that can be used by all organisms (plants included). After photosynthesis, plants store glucose as complex carbohydrates, such as starch. How is saliva involved in making glucose available for cells to use?

Photosynthesis (converting light energy into chemical bond energy of glucose):

$$CO_2 + H_20 + \text{sunlight/chlorophyll} = C_6H_{12}O_6\ (\text{glucose}) + O_2$$

All organisms break apart the glucose molecule to get the stored energy. The process of breaking apart the glucose and getting the usable chemical bond energy is called "respiration." It can occur in two steps: (1) anaerobic respiration (without oxygen) and (2) aerobic respiration (with oxygen). "Fermentation" is another name for anaerobic respiration as done by yeast cells.

Respiration (releasing chemical bond energy from glucose):



OBJECTIVES

To demonstrate yeast cell fermentation of juice by qualitative evaluation of fermentation products. In this series of laboratory experiments, students will:

- Use yeast cells to ferment fruit juice and then evaluate the fermentation products. Remember that fermentation is a form of anaerobic respiration, so the yeast cells do not get all the energy out of the glucose. Instead, some of the energy remains trapped in the alcohol, the waste product left by the yeast. To other organisms (such as *Daphnia* and people), the waste product alcohol is a drug.
- Test the effects of the fermented juice on the heart rate of *Daphnia.*
- Distill the fermented juice and condense the alcohol vapors. Test for the presence of pure alcohol.

MATERIALS

- 2 wide-mouth bottles
- Fruit juice
- Yeast culture
- Nalgene tubing
- L-shaped glass tube
- #6 rubber stopper with 1 hole
- Test tube
- Bromthymol blue solution or lime water
- Incubator set at 28° C
- Masking tape
- Watch glass or crucible
- Depression slide with cover slip

PROCEDURE FOR THE TEACHER

The procedure as written is complete, although more capable students appreciate the opportunity to design their own setups. Students undertaking this laboratory should know how to determine the density of pure alcohol, recognize the differences

in the boiling points of alcohol and water for distillation, and recognize how to use the microscope and locate parts of the *Daphnia.*

(Note: When the students test for the presence of pure alcohol, be sure the proper safety precautions are taken when burning the "alcohol." The density of the distilled alcohol should approach .80 g/ml.)

PROCEDURE FOR THE STUDENT

Fermentation Setup

• Using a 10 ml graduated cylinder, take mass and volume measurements and calculate the density of the juice. Record value data in a table. (Remember to get the mass of the clean, dry graduated cylinder BEFORE you begin.)

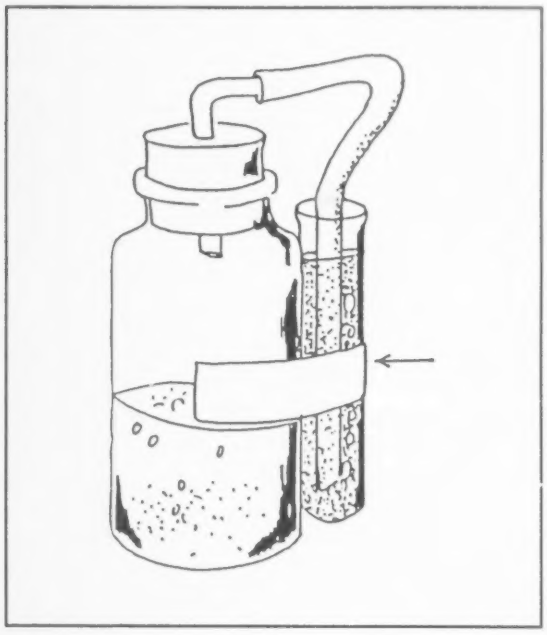
• Pour 100 ml of juice into each of two wide-mouth bottles. Inoculate one bottle with 1 ml of yeast suspension. Record observations such as smell, color, microscopic exam of yeast, etc. Keep the second bottle as a control.

• Tape a test tube containing 15 ml of bromthymol blue or lime water to the outside of the wide-mouth bottle.

• Cover the wide-mouth bottle with a rubber stopper fitted with glass and nalgene tubing. Submerge the end of the tubing in the test tube, so gases that are emitted will bubble through the indicator solution.

• Place the setup in the incubator for 3 days. Record observations daily. Check yeast population with microscope.

• Open the bottle and smell the contents. Record observations. Carefully decant 10 ml of the juice into a clean, weighed graduated cylinder. Record mass and calculate density.



Bioassay Using Daphnia

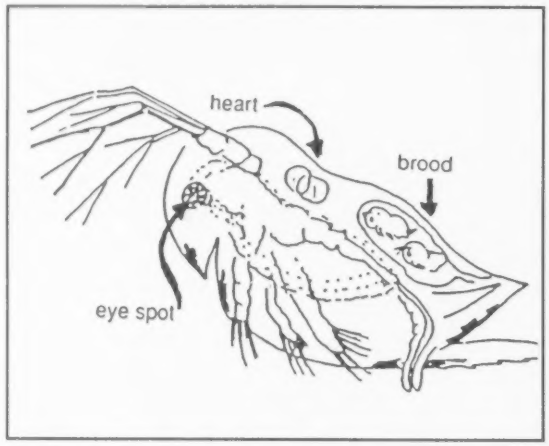
• Determine if the fermented juice affects the heart rate of the organism. Capture one *Daphnia* and, using a microscope and depression slide with coverslip, calculate the heart rate (beats per minute) of the organism.

• Carefully suction off the water and replace it with "control" juice. Calculate heart rate in the control juice. (Dilute 1:10 if control juice is toxic.)

• Dilute the fermented juice 1:10 (1 part fermented juice to 10 parts water).

• Suction off the "control" juice and replace it with the diluted "fermented" juice. Calculate the beats per minute in the diluted mixture.

• Suction off the diluted mixture and replace it with 100% (undiluted) mixture. Determine the beats per



minute if the organism survives.

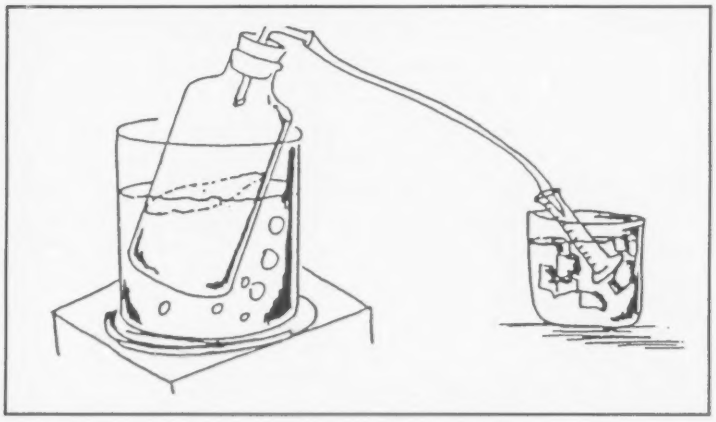
• Repeat with two *Daphnia* and average the results. Record the observations.

Distillation of Fermented Juice

• Place the wide mouth bottle into a beaker of water and gently boil the water over a hot plate. Carefully monitor the temperature of the water, so the juice remains below 98° C.

• Place the end of the nalgene tubing into a clean, dry, weighed, graduated cylinder. Place the cylinder into cold water, being especially careful NOT to allow water into the cylinder.

• As the "alcohol" fumes come down the tube, they will condense in the cooler graduated cylinder. Record the volume of liquid collected and get the mass. Calculate the density of the distilled alcohol.



• Pour the "alcohol" in the watch glass and carefully smell it. Record your observations. Light the alcohol in the watch glass. It should burn a clear (light yellow to almost white) to blue flame, if pure.

(See DATA/OBSERVATIONS sheet, Table 1, and Table 2 at the end of this activity.)

DISCUSSION QUESTIONS

1. What evidence do you have that the yeast cells were alive and growing after 3 days in the juice? Do you suppose that the yeast cells would continue to grow indefinitely if left in the bottle? Why or why not?
2. What evidence do you have that the juice was fermented by the yeast?
3. Did the density of the juice change as fermentation proceeded? How might density be used to estimate the amount of alcohol present in the fermented juice?
4. What experimental evidence do you have that alcohol is a drug? Discuss how drugs, such as cocaine, might affect neural transmission.
5. Why do you suppose the waste product of one organism has such a detrimental effect on that organism and others that might consume the waste product?

HELPFUL HINTS

• Teachers should try the procedures once to become comfortable with them.

• Students should work in groups of 3-4 and pool their data.

• Each group may supply its own juice (apple and guava work very well). Three-five grams of table sugar in 100 ml of water may be substituted for the juice.

• Students may want to familiarize themselves with the *Daphnia* because heart rates can be very fast (120+ beats per minute). Let students work out a method for counting.

(Note: Most of my students found it better if one counted while another one looked through the microscope and tapped the table for each heartbeat. This led to some interesting discussions on reliability of data and the need for replicates. This discussion should be encouraged, and other examples of difficulties encountered in "bioassays" should be brought up.)

Answers to Discussion Questions

1. Possible answers:

• Microscopic evidence = increase in yeast cell concentration.

• Increase in carbon dioxide production.

• Increase in "sediment" (yeast cells) deposited on the bottom of the bottle.

2. Possible answers:
• Decreasing density of juice.
• Increased carbon dioxide production – btb turns yellow to orange.
• Distillation of alcohol.
• Fermented juice affects *Daphnia* heart rate.

3. Density decreases as juice ferments, and sugar is converted to carbon dioxide and alcohol.

4. Drugs cause a change in bodily functions. Stimulants, such as cocaine, block specific reabsorption sites for neural transmitters and thus promote continuous firing of the neurons. Depressants, such as alcohol, decrease the ability of neurons to transmit information and can slow down bodily functions.

5. Possible answer – Waste products are waste products because the first consumer has removed the most readily available energy from the food. If the metabolism of the second consumer is similar to that of the first consumer, chances are the first consumer's waste is also a waste to the second. The second consumer then has the added problem of disposal without the gain of energy experienced by the first.

Caution

Do NOT distill alcohol near an open flame. Use a hot plate and keep the temperature of the water bath below 100° C. Alcohol can be detected after 48 hours. Avoid fermenting juice longer than 5 days. (Contaminating bacteria sometimes start to form acids and distort results.) Carry out distillation on the 4th-6th day. Refrigerate to stop fermentation. Save a 5 ml sample sealed in a test tube if heart rate counts are not complete. Allow 4-5 hours of actual laboratory time. Prepared eighth grade students in 45-minute classes can manage the procedures (even the distillation) within those time constraints.

DATA/OBSERVATIONS **(Record observations on this page and data on the next):**

Diagram of Yeast

Day 1 Set-Up _____

_____

_____

_____

Day 2 Fermentation _____ before

_____

Day 3 Fermentation _____

_____

_____

after

Day 4 Daphnia Heartrate _____

_____

_____

Day 5 Distillation _____

_____

_____

_____

Table 1: Density of Juice Solutions

	Before Fermentation	After Fermentation	After Distillation
Volume			
Student 1			
Student 2			
Student 3			
Student 4			
Vol. Average			
Mass			
Student 1			
Student 2			
Student 3			
Student 4			
Mass Average			
Density			
Student 1			
Student 2			
Student 3			
Student 4			
Den. Average			

Show calculations:

Table 2. Changes in Daphnia Heartrate

	Water		Juice		Fermented Juice 1/10 x		Fermented Juice 1x		Distilled	
	beats/15 sec	bpm	b/15s	bpm	b/15s	bpm	b/15s	bpm	b/15 s	bpm
Student 1										
Student 2										
Student 3										
Student 4										
Average										

Name: _____

Section: _____

46-50: Calculate X the amount of alcohol in the following 10 ml sample of fermented juice: (Remember: Density = Mass/Volume)

Density of fresh juice: 1.004 g/ml
Density of alcohol: .80 g/ml
Density of fermented juice: .96 g/ml

Liquid	Mass (g)	Volume (ml)	Density (g/ml)
alcohol	0.8 X	X	0.8
fresh juice	_____	10 - X	1.0
fermented juice	9.6	10	0.96

Section V - Developing Research & Writing Skills

Vital Capacity: Worthwhile Research

Bob Melton
Edmond, Oklahoma

Measurement of lung capacity is a very common lab activity in life science courses. In many cases, the results of student measurement of "vital capacity" (VC), "tidal volume," "expiratory reserve volume," and the like are correlated to various lung diseases and respiratory conditions. Although this may be interesting information, a good lab activity is to hand this kind of research over to the students and use measurement of student "vital capacity" as an opportunity for students to develop hypotheses and work with a large amount of data. The lab and the final lab report take several days to complete, but the students' involvement in hypothesis formation, data manipulation, and conclusion development are well worth the time spent.

OBJECTIVES

- To identify and describe six breathing volume measurements.
- To develop a complete and reasonable conclusion, supported by at least two kinds of analysis of data generated from a test of a hypothesis that does not duplicate those written by other members of the lab team.
- To analyze factors that affect an individual's "vital capacity."

MATERIALS

- Device for measuring student "vital capacity" (such as the Phipps and Bird Student Wet Spirometer, a Portable Dry Spirometer, or a Lung Volume Bag).
- 1 per student – Dubois Body Surface Chart (or other such chart relating body size to surface area or lung capacity).

PROCEDURE FOR THE TEACHER

Day 1 – Begin the first day of the lab with a 20-minute discussion with students about lung volume measurement. Briefly explain vital capacity, expiratory reserve volume, inspiratory lung volume, tidal volume, total lung capacity, and residual volume. Also explain the Dubois Body Surface Area Chart and show students that a person's vital capacity can be predicted with the chart if his/her height and weight are known. (The constant 2.0 is multiplied with the body surface area to obtain a female predicted vital capacity; the constant 2.5 is multiplied with the body surface area to obtain male predicted vital capacity.)

Devote the next 15 minutes of class time to the measurement strategies to be utilized on Day 2 of the lab and on the format of the lab report that each student will write. The report format for this lab is:

- Introduction.
- Hypothesis.
- Procedure and Materials.
- Data.
- Conclusion.
- Bibliography (at least 3 sources).

Tell the students that each of them is to develop a hypothesis for the lab that is different from any other hypothesis in his/her lab group (4 or 5 students), and he/she will be obtaining data for all students in all course sections participating in the lab. Begin a brainstorming session in which students chart the types of information they will need in order to test their hypotheses. In addition to student gender, height and weight, students often want to know if test subjects smoke, consider themselves to be athletes, have respiratory ailments, etc. Students very often discuss confidentiality of this information and brainstorm methods to protect individual student data.

Student hypotheses are quite varied and often reflect personal experience. Student athletes often want to compare vital capacities of athletes to those of non-

athletes, always predicting higher VC for athletes, of course! Students who have experienced lung ailments often wish to investigate the vital capacities of people with lung ailments compared with those who report no lung ailments. Invariably, one particularly athletic young man (or woman) will want to compare male athletes with female athletes.

Student talk about possible hypotheses often lead to discussions of what vital capacity shows, what it means for a person to be "in shape," and how comparisons cannot be valid unless some mechanism is developed to account for size and gender differences. In subsequent class sessions, the teacher-facilitator can help students find solutions to these questions by using the Dubois Body Surface Area Chart and spend time talking about the necessity for pooling data.

Day 2 – Students measure their vital capacities and enter their data on a chart for that purpose. Designate a student team to run the test machinery and acquire the data. Students who have tested or who are waiting to test may work on researching and writing drafts of their lab introductions, hypotheses, and procedures. (Special note: Students with severe respiratory ailments should be exempted from contributing data to this lab.)

Day 3 – Give students copies of all data obtained from class sections. Devote the remaining time of the class session to work in lab groups as students discuss their hypotheses, manipulate their data, and develop conclusions. The teacher-facilitator can walk from group to group, helping with ideas and asking questions of students to aid them in solidifying their hypotheses and conclusions.

Day 4 – The teacher again serves as resource person, checking with each group during this time.

Day 5 – Lab reports in their final published phase are due.

PROCEDURE FOR THE STUDENT

Day 1 – Students develop hypotheses for the lab, brainstorm information needed from each student, and begin researching the additional information about lung volumes necessary to write the lab introduction.

Day 2 – Students test their vital capacities by whatever method necessary for the spirometer in use. A student team operates the test equipment and records the data. All students begin a draft of their lab reports (introduction, hypothesis, procedure).

Day 3 – Students obtain data and begin data analysis that will test their hypotheses and lead to the development of viable conclusions. They will complete the lab report drafts overnight.

Day 4 – Students work at least a half hour in their lab groups, revising their lab report drafts. Since all hypotheses in a lab group are different, students can explore the different ideas that a single set of data can represent. In their groups, students work with one lab report at a time and check for completeness of the report, adherence to report guidelines, and validity of the conclusion.

Day 5 – Completed lab report due.

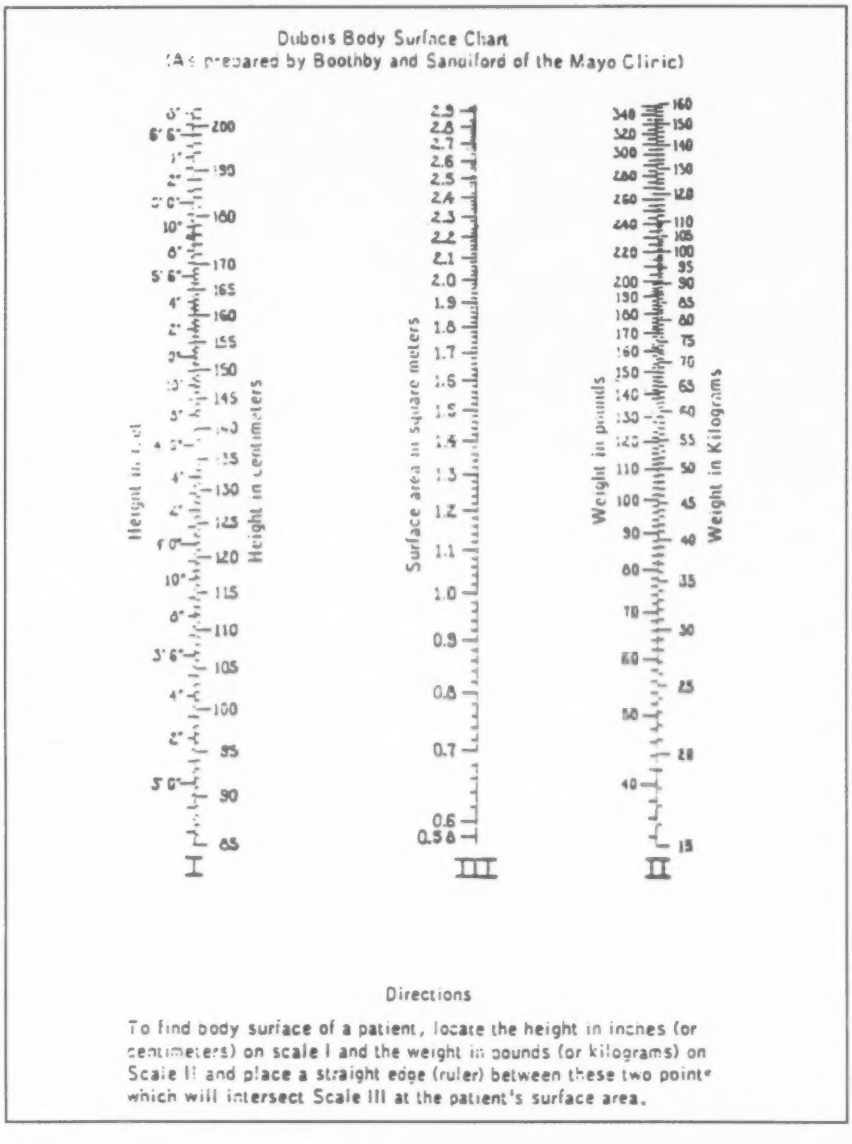
HELPFUL HINTS

Lab report grading can often be facilitated by the use of a checklist, made available to each lab group, in which the items that will be graded are outlined. The teacher should check to see that the lab report format was followed and then focus on the student's hypothesis and conclusion. If the conclusion is flawed, the report is scored as "incomplete," and after a short, clarifying conference, the paper is returned for the student to revise for a grade. In addition, lab group members share bonus points for their good revision of complete and well-written reports.

SUMMING UP

The lab takes a few more days than is normally given to

this topic in many classes, but its rewards are many. First, it hands the lab operation and design over to the students, thereby freeing the teacher to be a facilitator. Second, it mirrors science in a number of respects: (1) many different conclusions can be obtained from a single set of information; (2) pooled data is valuable; (3) using mathematics to verify conclusions is necessary; and (4) collaboration is rewarding. Finally, it provides an opportunity for students to practice technical and persuasive writing as they adhere to a prescribed format and try to provide support for their conclusions.


Dubois Body Surface Chart
(As prepared by Boothby and Sandiford of the Mayo Clinic)
Height in centimeters
Surface area in square meters
Weight in pounds
Weight in Kilograms
Directions
To find body surface of a patient, locate the height in inches (or centimeters) on scale I and the weight in pounds (or kilograms) on Scale II and place a straight edge (ruler) between these two points which will intersect Scale III at the patient's surface area.

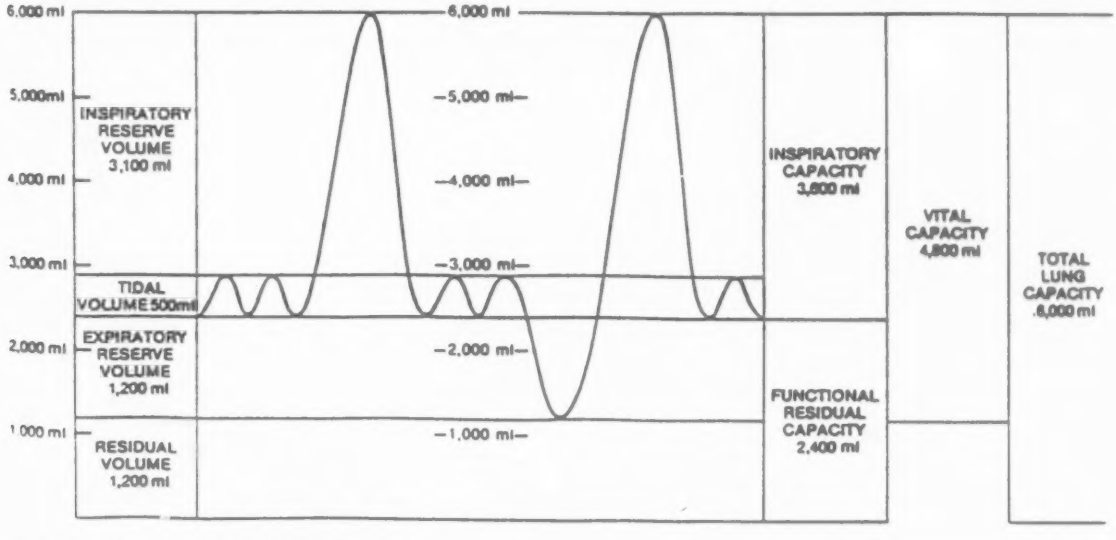
Rubric:Vital Capacity Lab Report

	Self		Peer		Teacher		
	Yes	I	Yes	I	Yes	HQ	I
Introduction- description of breathing volumes, description of equipment							
Hypothesis- stated in proper terms, not duplicated by others in lab group							
Procedure and Materials- all materials listed, step-by-step directions listed.							
Data- all data from all classes listed in table form							
Conclusion- complete and reasonable, relates to hypothesis, contains two kinds of analysis (graphs, mathmatics, etc.)							

Key: I - Incomplete (must revise this item) Yes - Meets minimum criteria HQ- High Quality

Unit Outcomes

Outcome #1- Identify and describe six breathing volume measurements
Outcome #2- Develop a complete and reasonable conclusion, supported by at least two kinds of analysis of data generated from a test of a hypothesis that does not duplicate those written by other members of your lab group.
Qualifier #1- Measurement of your lung volume and the display of data for analysis by all A&P classes.
Qualifier #2- A properly written lab report that contains the properly labeled sections in their correct order.



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Ecological Challenge -Global Warming

Jane Bricker Maczuz
North Ridgeville, Ohio

Integrating the scientific method with critical thinking skills, students are to use common household materials to design an experiment that simulates global warming.

OBJECTIVES

By following the basic tenets of the scientific method, students will develop a demonstration that illustrates global warming ("The Greenhouse Effect") using common household items. While developing an exercise that shows that impact of increased atmospheric carbon dioxide on temperature, the students will practice basic lab writing skills by researching, hypothesizing, designing a controlled experiment, collecting and analyzing data, and presenting their conclusions to their peers for critical analysis.

GRADE LEVEL

Grades 9-12

MATERIALS

- 1/4 inch plastic tygon tubing
- #4 rubber stoppers
- Light sources
- Clamps
- 100-watt light bulbs
- Thermometers
- 3 two-liter plastic bottles
- Glass tubing
- Alka-Seltzer® tablets
- Sodium bicarbonate
- Bromothymol Blue
- Vinegar

PROCEDURE FOR THE TEACHER

Before the lab – Assign student lab groups to bring in three 2L bottles. Assemble all materials needed for activity.

Day 1 – Inform all students that each lab group is to develop a controlled experiment that demonstrates global warming by using only the materials made available to them in the lab. Do not explain the possible use of any of the materials to the students. Any additional materials that they may wish to use may only be used with teacher approval. Students are then given the remaining period to research and develop their experimental design. They are instructed to let their imaginations run wild. Originality will gain them extra points.

Day 2 – Students are to set up and run their experiments. Data are collected and analyzed. Students are to determine the mean and range of their temperatures. They will also generate computer graphics for use in their presentations and lab reports by using the computer and appropriate software programs. Assign lab reports for homework.

Day 3 – Students will present their demonstrations to the class. Questions about the design are encouraged. Validity of the designs will be discussed by the class, and suggestions for improvement will be considered.

(Safety Note: Students are to wear goggles at all times during the lab and should be cautioned about the possibility of blowing stoppers out of the 2L bottles while generating the carbon dioxide.)

PROCEDURE FOR THE STUDENT

1. *Problem* – In teams, develop a demonstration that illustrates global warming ("The Greenhouse Effect") using common household items.

2. *Research* – Go to the library or use available sources in the room and research the topic. Be sure to make an outline of information and also include a bibliography (Section VIII, References) at the end of the lab report.

3. *Hypothesis* – Formulate a hypothesis for your experiment that illustrates global worming.

4. *Materials* – Any materials made available by the teacher may be used during the lab or materials may be brought from home. Materials brought from home must be approved by the teacher. List items used in the demonstration in the lab report. Two-liter bottles must be used, and a light and a carbon dioxide source are also required.

5. *Experimental Design* – A control must be included in the demonstration. Provide an outline of the demonstration design in the lab report, and explain your setup in front of the class.

6. *Results* – Develop a chart, graph, etc., to record results of the experiment. Determine the mean and range of the data.

7. *Discussion and Conclusion* – Be sure to include future improvements on the design of the demonstration in the lab report.

8. *References.*

HELPFUL HINTS

Make LaMotte carbon dioxide testing kits and air pollution sampling equipment available, if possible. Bromthymol Blue will not change colors in normal air.

SUMMING UP

This exercise is helpful in reviewing the scientific method with students because it challenges their creativity and critical thinking skills. With teacher modifications, it is also a way to introduce students to the format for written lab reports.

Section VI - Student Projects

Adopt a Tree Project

Sharon J. Fisher
Des Moines, Iowa

Every kind of tree is different. Trees have existed for more than 200 million years and are the largest life form to inhabit the earth. Trees, like people, have special characteristics that help us to recognize them. Too often, we forget the importance of plants in our environment, so this project will focus on the importance of trees in our botanical world.

OBJECTIVES

- Students will observe, collect, record, organize and present biological data.
- Students will experience biology out of doors.
- Students will analyze in detail one plant species.

MATERIALS

This project can be done with materials that students will have around the house or that are available at school. No additional equipment is needed.

PROCEDURE FOR THE TEACHER

Students need to spend more time in direct observation of nature. This project is intended to familiarize students with a very common part of their environment, a tree. It cannot be just any old tree, however, but a special tree — their tree.

Teachers may want to spend some time on tree identification, but that is not necessary, as students can easily identify their tree with a key.

Some help may be needed in showing students how to press and preserve collected leaves, and students will need access to the library in order to do the research portion of this project. Some time will also be required to show students how to calculate the height of their trees, If data analysis is included, students may need instruction in calculating means, modes, ranges of size, etc.

PROCEDURE FOR THE STUDENT

Choose a mature tree, one that can be visited easily and often. Choose a DECIDUOUS tree, not a pine tree or an evergreen. If possible, select a tree whose name is known, as it will save time identifying it. Books can be found in the library or classroom if it is necessary to identify the tree.

COLLECTION

Collect 5-6 leaves from the tree BEFORE and AFTER they begin to change color in the fall. Preserve the leaves by pressing and laminating them.

Make a bark rubbing of the tree. Place a very thin piece of paper or cotton cloth over the bark and, using the flat, long side of a crayon, carefully rub the paper or cloth until the bark's pattern shows through. (Repeat until you have a a rubbing with which you are happy.)

MEASUREMENTS AND OBSERVATIONS

Decide how to present this information. A data table or a graph may work well. In some cases, drawings will be needed — use colored pencils and make accurate and complete sketches.

1. Calculate the tree's height.
2. Measure the circumference or distance around the tree trunk. Use a crayon and ruler to mark in several places 4½ feet up from the ground. With a tape measure or string and ruler, measure the distance around the trunk at this height.
3. Estimate the age of the tree — perhaps someone remembers when it was planted.
4. Draw the general shape of the tree. Is it shaped like an umbrella? Is it tall or slim, or is it flat, rounded or pointed on top?
5. Locate a terminal bud — that's the bud at the very end of a branch. Measure how much the branch grew

during the last growing season by following the branch back from the terminal bud until the first growth rings can be seen. (These will be rings around the branch, and they show where the terminal bud was last year.)
6. Sketch the branch, including at least 5 lateral (side) buds and the terminal bud. This will show the pattern or arrangement of leaves on the branch.
7. If the tree is bearing fruit (including nuts), sketch one. How are seeds of the tree dispersed? (Wind, water, animals?)
8. Examine the tree for any trauma caused by the wind, ice, lightning, fire, insects or people. Speculate from these observations as to the condition of the tree. Is it healthy? Are there any advantages or disadvantages to the tree being located where it is? What is the natural environment of the tree? Try to remember the tree during other seasons; how is it different?

Daily Observations
Several times between now and when the project is due, check the tree and record the following information: first signs of leaves turning color, date first leaves begin to fall, any animals that might be using the tree for a temporary or permanent home, any signs of disease or fungi on the tree, any lichens growing there, any damage to the tree in any way.

Optional
Take the length and width measurements of 100 leaves from the tree — calculate the mean, mode, and range of size. Graph the data.

CLASSIFICATION
Reference books will be needed to determine the official names of the tree. Scientists call this SCIENTIFIC CLASSIFICATION. It is a way of describing living things while showing relationships to others. A sample is started below:
KINGDOM = Plantae
PHYLUM = Anthophyta
CLASS = Angiospermae
ORDER =
FAMILY =
GENUS =
SPECIES =

RESEARCH/REPORT
This part of the project will require library work. Research information about the species of the tree. Where did it come from? Was it brought to this country or is it a native tree? What is this tree good for? Are there any commercial products made from the tree? Does the tree species have any historical value or is it famous for anything? Look for interesting facts and myths about the tree. Some trees are considered very magical or holy by different groups of people.

Is the tree a soft or hardwood tree? What is the average life span of this tree species? Find a picture of the tree's flower and fruit (yes, it will have them) and sketch them. Color would be nice, if possible!

Make any additional comments about this tree or about trees in general that would add to the quality of the report.

DIRECTIONS FOR THE FINAL REPORT
Each student's final work may take any form he/she likes as long as it includes everything required below. Notebook reports or large posters can be made, and except for the collection part, it is even possible to do the whole report on video.

Each report should include:
• Some kind of introduction or cover page with student name, period, date, and name of the tree. If posters are made, they still need titles.
• Collected leaves and bark rubbing.
• Measurements and observations arranged in a logical order. Data tables, graphs, drawings, etc., should be used to show that the student has taken the time to make sense out of the information he/she has gathered.
• Tree classification.
• Library research that tells more detail about the tree species.
• Bibliography … This includes all the books, magazines, etc., used to obtain information.
• Extra … A photograph of the student and his/her tree; collected leaves that are in the process of changing

colors; some ideas that would help conserve and care for trees.

HELPFUL HINTS

- Begin immediately at the beginning of the school year with this project. Although it is meant to be done outside of class, teachers should check several times to be sure students do not put this report off until the last minute.
- It is helpful to allow a couple of library work days.
- If a laminator is not available for the leaves, clear contact paper works well.
- If possible, recruit English teachers to do a brush-up on report writing, especially bibliographies. This is very helpful.

SUMMING UP

This is a wonderful way to get students outside to actually observe nature. It provides a link to many other areas of study throughout the year, and students do not forget their trees.

The Fungi Feast

Kevin Collins
Sandpoint, Idaho

The "Fungi Feast" is a summary activity for a unit on bacteria and fungi. The main purpose of the activity is to emphasize the positive role yeast (a fungus) has on students' lives and to encourage student participation in a tasty lab where homemade baked goods are shared.

OBJECTIVES

- To give students an opportunity to experience science in their everyday lives.
- To provide the students with a multi-sensory experience of the positive part fungi play in their lives.
- To give middle school/junior high students and their parents an opportunity to work together on a school project.
- Since most families purchase bread for home consumption, this activity serves to broaden the students' horizons by giving them an opportunity to learn a new skill, creating tempting baked goods using a common fungus, yeast.

GRADE LEVEL

Grades 7-12

MATERIALS

A collection of recipes, of varying levels of complexity, for baked goods using yeast as the leaven. Caramel rolls, cinnamon rolls, and soft pretzels are all student favorites.

PROCEDURE FOR THE TEACHER

Before the lab – Make the recipes available about a week before the event to give beginning bakers time to practice before the feast. Junior high or middle school students can be encouraged to seek help from parents in their initial attempts at baking. This lab can provide an opportunity for a positive sharing time between students and their parents.

Day of the lab – Clean all table tops and lab counters thoroughly. Store all chemicals in secure storage cabinets to avoid accidental poisoning.

PROCEDURE FOR THE STUDENT

Students are asked to bake bread, rolls, etc., at home to bring in to share with the class. Recipes are provided by the teacher, the only requirement being that all baked goods must contain yeast, a common fungus. Students may practice their baking skills prior to the day of the activity, so they can share their best efforts with their classmates.

HELPFUL HINTS

To encourage student participation, this activity is graded as an optional lab. Students supplying baked goods that they have made on their own receive an "A" for a homework grade that will be counted into their average. Students who choose not to bring in a baked item receive no grade but do participate in the feast.

A complementary activity that goes well with the "Fungi Feast" is to make homemade root beer. Using the recipe below, make the root beer at least one week before it is to be used to allow adequate time for the yeast to carbonate the beverage.

Root Beer

- 2 cups sugar (1-500 ml beaker)
- 3 tablespoons of root beer extract (45 ml) or 1 tablespoon (15 ml) of root beer concentrate
- ½ teaspoon of yeast (2.5 ml)
- 4 liters of warm water (approximately).

Instructions: Dissolve the yeast in a cup of warm tap water. Divide the sugar and root beer extract evenly into two 2L plastic ** soda bottles. Add enough warm tap

water to each 2L bottle to dissolve the sugar. Pour 1/2 cup of the yeast and water mixture into each 2L bottle and mix thoroughly. Fill the remaining space in each bottle with warm water. Allow the bottle to sit open in a warm place for 24 hours. Then cap the bottle tightly and leave out at room temperature until the bottle begins to stiffen due to the build up of carbon dioxide. Refrigerate until ready to serve.

* Root beer extract can usually be found in the spice aisle of most large grocery stores. Hires® brand root beer extract and Schilling® brand root beer concentrate have both been used with good results. The Hires® product makes a slightly better-tasting root beer.

** **Do not use a glass container** as the pressure from the buildup of carbon dioxide may cause the bottle to explode. Plastic bottles tend to stretch with pressure and are less likely to burst.

SUMMING UP

This lab is my students' all-time favorite. Students of all ability levels try their hand at baking with an equal opportunity for success. Individuals are often very proud of their "work." The "Fungi Feast" works especially well for the last half of a class on Friday afternoon.

Genethics: What Are the Issues in Genetics?

Judith Williams
Central City, Nebraska

This cooperative team activity is an opportunity for students to become exposed to current scientific research involving genetic diseases, genetic engineering, and genetic screening and to creatively express their team's feelings on ethical issues in genetics as they relate to science, technology and society.

OBJECTIVES

- To develop an awareness of the "newest" scientific technological innovations in the area of genetics.
- To develop skills for analyzing and evaluating scientific research currently being done and its effects on society, especially in biogenetics.
- To develop critical thinking skills necessary for making well-formed personal decisions about ethical issues.
- To develop communication skills necessary in order to effectively reach a group consensus on controversial bioethical issues.
- To develop skills in creatively expressing feelings and opinions about bioethical issues through written or visual communication.

GRADE LEVEL

Grades 10-12

MATERIALS

None required. Optional materials may be needed to complete teams' creative activities.

PROCEDURE FOR THE TEACHER

Before the lab

- Determine the purpose for the students to complete this activity. Is it to demonstrate competency in the skills of decision making, critical thinking, and creative thinking? Is it to learn to work cooperatively in small teams? Is it to practice oral/written communications using these processing skills?
- Decide the prerequisites for dividing the class into small cooperative teams.
- Prepare "student procedure" handout for the activity.
- Establish guidelines, if any, for preparing or communicating teams' creative projects.

During the lab – Act as a facilitator as students actively engage in the learning process.

PROCEDURE FOR THE STUDENT

Time Schedule

Days 1-3 – Complete steps 1-4 under "What To Do."
Day 4 – "Share Day" for communicating team's feelings on ethical issues.

Awareness – Newspapers are probably the number one source used by the general public to receive up-to-date information on genetic research. In this activity, you will be exposed to some of the"latest news."

Terms to Know:

- GENETIC THERAPY – Replacement of a defective gene with a normal one.
- GENETIC SCREENING – Testing to identify individuals at risk for a particular genetic disease or for bearing a child with such a disease.
- GENETIC ENGINEERING – Ways of controlling heredity by replacing missing or defective genes with healthy ones.

What To Do:

1. READ – Do you know the latest news in plant research?

- Lighted Christmas trees are a dramatic example of a branch of genetic engineering that implants luminosity genes from bacteria and fireflies into normally nonglowing plants.
- Laboratories around the world have used glowing-plant disease bacteria to study how crops succumb to

rot and blight.

2. DISCUSS/RECORD team responses to "stop and think" questions:
• Do you believe researchers should be allowed to create the "glowing" trees simply for us to purchase?
• Do you feel these "glowing" trees would be beneficial to our society?
• Does it make a difference to you as to the kind of plant being researched?
• Do you believe that researchers should be allowed to do research on crop plants?
• Would the type of crop make a difference?
• Do you believe it would be important to do research on a crop such as corn if researchers have been successful with crops such as soybeans and tomatoes?
• About which questions did the team have unanimous agreement? Consensus?

3. READ – Do you know the latest news in medical research?
• A lot of attention has been devoted to animal rights groups, and many in these groups believe that animals should not be used in research.
• Researchers have solved one of the medical mysteries of the 20th century by isolating the gene responsible for the lethal, inherited disease of cystic fibrosis.
• Among the new treatments envisioned for diseases in which the lethal gene has been isolated is the replacement of the victim's defective genes with normal ones.
• Knowing the gene responsible for a lethal disease will enable geneticists to use it as a "probe" when using fetal tissue samples to determine whether a fetus will develop the disease.
• Researchers have had preliminary success using an alternative to sidestep surgical grafting of new arteries onto diseased blood vessels. Implanting genetic material into heart tissue stimulates growth of new blood vessels.
• Researchers have devised a testing method to screen a woman's eggs for certain genetic defects before she becomes pregnant. This technique would enable women to avoid passing along a genetic disease without necessitating an abortion. This method can be used with couples who are identified as disease carriers through genetic screening techniques. The test should also be capable of screening for the genes that carry Tay-Sachs disease, sickle-cell anemia and cystic fibrosis.

4. DISCUSS/RECORD team responses to "stop and think" questions:
• Do you believe it is morally acceptable for our society to allow research on humans?
• Do you feel that society has benefited from medical research?
• What are the pros/cons of using humans for research?
• Some people think that, instead of trying to cure genetic diseases, society should try to prevent babies with diseases from being born. What are the the pros/cons of this thinking? Did the team have unanimous agreement on any of these questions? If so, which ones?

5. EXPRESS the team's feelings toward genetic research by doing one of the following:
• Create a poem to be read.
• Create a song to be sung.
• Create a play to be acted out.
• Create a story to be read out loud to the class.
Each team may choose to do more than one creation!

6. "SHARE DAY" – Teams will communicate to classmates their creations that express each team's feelings towards genetic research. How creative teams can be in their presentations will help the class to really "stop and think" about ethical issues in relation to genetic research.

ENRICHMENT ACTIVITIES (Optional)
• Individual students may want to complete his/her own creation of a poem, song, play, or story expressing his/her feelings toward the ethical, legal, religious or philosophical issues in genetics.
• Students may want to make a list of books available in the school library in the field of genetics. These books can also be checked out and used to set up a display in the classroom.

• Some class members may want to select genetics books, read chapters that are of interest to them, and prepare a written summary to be handed in, make an appointment to share/discuss the information with the teacher, and/or give an oral presentation to the class about what they have learned.
• Others may want to read magazine articles that include up-to-date information on genetics, gene mapping, gene probes, genetic diseases, gene therapy, genetic engineering, etc., and prepare a written report, a visual display, or an oral presentation to share the information with classmates.
• Students may also like to create a wall hanging illustrating or informing others on "genetic news."
• Students may be recruited to form debate teams. A "class debate" may be held after students have gathered background information.

HELPFUL HINTS

• In the fall of the school year, the teacher may put up a large wall hanging in the classroom called "Food for Thought!" Newspaper clippings of biological interest are hung on it after the "news" is discussed in class. Students become familiar with genetics and genetics issues throughout the school year as they are exposed to the "latest news." That "news" is then used to update the genetic information on this activity.

• It is important that students be provided with guidance and stated expectations if this activity introduces them to a new processing skill. Guided handouts are distributed and expectations are modeled for students when introducing these new processing skills in the classroom. Students complete a variety of activities throughout the year that allow them to practice/demonstrate the skills involved in this activity, and this lab is also used as a performance assessment to demonstrate skill competency at the end of the genetics unit.

SUMMING UP

This activity increases student awareness of the controversial issues that develop along with scientific technological innovations. It provides an opportunity for students to clarify their opinions toward those issues by creatively expressing their team's feelings about ethical issues in genetics as as they relate to science, technology, and society. The activity can be used to have students practice the skills of decision making, critical thinking, creative thinking, working cooperatively in small teams, and oral/written communications, or it can be effectively used by teachers as a student-outcome, performance-based assessment tool to have students demonstrate competency in these processing skills.

Section VII - Using Food in the Classroom

The Pizza Lab

Barbara Cauchon
Brookline, Massachusetts

This activity was created to counteract the students' cries of "I'm NOT an artist!" whenever they are asked to create a diagram during microscope labs or any other activity. The purpose of "The Pizza Lab" is to teach students basic drawing skills and proper diagram format, both of which will be used throughout the rest of the year. The activity also introduces the concept of how changing the magnification of an object under the microscope will change the field of vision. Students do this activity right in their lab notebooks and are encouraged to take notes so that they may refer back to them during future labs.

OBJECTIVES

- To learn some basic drawing techniques that will help students as they attempt to draw specimens during labs and activities.
- To clarify teacher expectations of how diagrams should appear in labs and activities students will do during the remainder of the year.
- To show the relationship between the level of magnification used in microscopy and the area of the field of vision.

MATERIALS

For the Teacher:

- Pizza slides
- Slide projector and screen
- Overhead projector, blank transparencies, markers
- Directions

For the Student:

- Paper (lab notebooks)
- Pencils
- Straight edge

PROCEDURE FOR THE TEACHER

The teacher will need to make his/her own pizza slides before doing this activity. A homemade cheese pizza loaded with toppings that will show up well in photographs, including pepperoni slices, onion rings, anchovies, sun-dried tomatoes, broccoli pieces, artichoke hearts, mushrooms, etc., makes a good example for the students. Take several shots of the pizza both before cooking it and after it is baked. (Use a standard 35 mm camera with flash, loaded with slide film.)

To simulate the difference in field of vision for the students, take a shot with the camera far enough away so that the entire perimeter of the pizza is shown and then take another closer shot, so that the images are larger, but the perimeter is no longer visible. Take several pictures at each distance of the uncooked and cooked pizza.

The day of the lab, set up the overhead projector next to the slide projector. The slide projector is loaded with pizza slides. Each projector is set up so that both will project their images on the screen at the front of the room simultaneously. The students should have their lab notebooks, pencils and straight edges ready before beginning.

(I introduce this activity by explaining that I do not consider myself an artist but that I have learned some helpful drawing techniques from a friend who is an artist which I would like to share with the class. I go on to say that, during the activity, I will explain the format the students will be using whenever they do diagrams in class. I pass out the student directions and ask the class members to attach them to their notebooks for future reference. I then proceed to go through the directions with the students, doing the activity with them by making my drawings on the overhead projector.)

Using the student directions as a guide, turn on the

projectors and explain that the class is going to draw a pizza, making the analogy of the pizza being somewhat like a microscopic organism that the students may be asked to draw in the future. Walk them through the directions for setting up their field of vision boundaries, adding crosshatches as guides, and beginning their drawings, while setting up the teacher drawing on the overhead.

After going through the first quadrant, let them continue on their own, circulating among the students, offering praise and suggestions. It is important to offer encouragement during this time to build student confidence in their abilities, no matter how primitive. Assure them that, with practice, they will all improve.

Teachers may then choose to show the difference between powers of magnification and visible field of vision. Using both the long and close shots of the same pizza in the projector, explain that the move from "low power" to "high power" can be simulated by moving between slides. Refer to the long shot of the pizza as a simulation of 100X and the close shot as a simulation of 400X. This is a wonderful visual tool to illustrate a concept which oftentimes confuses students during microscope use. Reinforce this concept when students begin actual microscope work by reminding them of the difference in the portion of the pizza they could see during this activity.

After completing the lab, further drawing exercises may be assigned, perhaps for homework, to give students more practice in diagram drawing. The more they do it, the better they get!

PROCEDURE FOR THE STUDENT

For most of this activity, follow the teacher's directions and draw 2 slides of a pizza. The general steps used to draw diagrams of specimens are outlined below for future reference. Remember, relax and take as much time as necessary, and this activity can be an enjoyable part of biology! You do not have to be artists to draw clear, well-organized diagrams. Careful attention to detail is all that is needed.

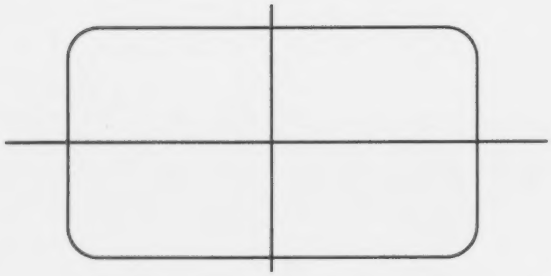
Diagram Information and Procedure

1. Diagram requirements:

- Diagrams are always done in pencil on plain white paper.
- Each diagram you do will always have a title (tells what it is you have drawn).
- If done under observation using the microscope, the diagram will have magnification power clearly indicated.
- Any labels will be drawn using a straight edge and placed on the horizontal.
- Labels will be written using clear handwriting and will be spelled correctly.

2. Starting the diagram:

- If making observations using a microscope, first draw a circle to represent the field of vision. This is the area seen when looking through the microscope. Choose a round object to trace the field of vision (petri dishes, bottoms of beakers, quarters, etc.) — just make sure that the size chosen reflects the amount of material being drawn. In the case of the pizza diagram, simply draw a square.
- Drawing lightly with a pencil, place a set of crosshatches over the area drawn to represent the field of vision. This will help orient you to the subject as drawing begins.
- What is the overall outline of the specimen? Is it round, oval, or irregular? Does it have a centralized body with limbs? Look at the outline of the specimen and ignore the details within; in the case of the pizza, the outline of the low-power pizza is a clean circle.
- Imagine that the specimen has a set of crosshatches drawn through it just like the ones traced onto the paper. (Students are now going to try to draw the outline of the specimen one quarter at a time.) Do not worry about the details inside at this time. The crosshatches, both imaginary and drawn, should help.
- Starting at the upper right quadrant, start to draw the outline of the specimen. Continue drawing the outline down to the lower right quadrant, over to the lower left



quadrant, then finish in the upper left quadrant. The sketch should look like the specimen which is being drawn. Erase and start again if there are mistakes. Work carefully and relax.

• Observe the outline of the specimen more closely. Is it thicker or darker than the rest of the specimen? If so, darken and thicken the outline on the paper. If not, leave the outline alone. Does the outline have any projections (like hair or cilia)? Look at the drawn outline carefully to make sure it is the best representation of the specimen's outline before moving on to the next page. In the case of the pizza, the outline is thicker and darker, so adjust the drawing accordingly.

3. Details of the drawing:

• Now focus attention on the area inside the outline of the specimen. Take a careful look. Are there smaller objects? What are their sizes and shapes? Are they dark or light in color? In the case of the pizza, look at the different things baked on it. There are irregular-shaped broccoli pieces; long, thin anchovies; clean, circular sausage pieces, etc.

• Starting at the upper right quadrant, start to draw in any details seen inside the specimen. Position the details using the crosshatches. If something is round, draw a circle to represent it in the appropriate place. If it looks thin and hairlike, draw the shape accordingly. Then move on to any other shaped objects.

• Once the upper right quadrant is filled, move to the lower right quadrant and do the same. Continue this until the entire drawing has been filled with detail.

• Now, look at the entire specimen. Are there areas of detail that are darker than others? Darken those on the diagram. Are there areas that are less dark? Lightly darken them in, keeping them lighter than the darkest details. Continue shading in the details, using the specimen as a whole to guide you. In the case of the pizza, the sun-dried tomatoes are the darkest; the broccoli is a bit lighter; the anchovies and sausage a bit lighter still, etc.

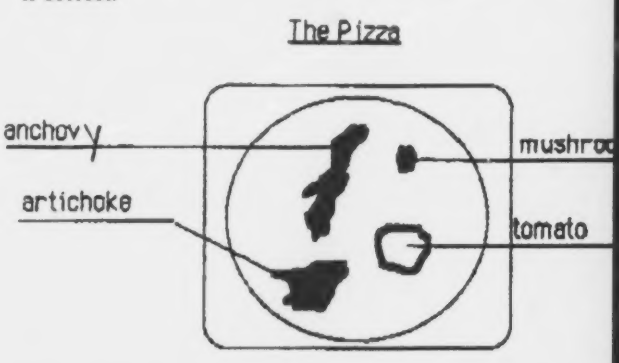
• After drawing in and shading the details, look at the drawing carefully, and then look at the specimen. Is there anything that should be added or erased to make it more clear? Are there any areas that should be redrawn? (That's what the eraser is for!)

4. Labels and title:

• After drawing the diagram, label any parts that can be identified. Usually a lab that includes drawing a diagram will have a series of parts to be found, drawn and labeled on the specimen.

• For each part labeled, find a good representation of the part and draw a horizontal, straight line (using a straight edge) from the part to an area outside of the diagram (outside the field of vision if it is a microscope drawing being done).

• To the right of this line, write the name of the part labeled. Write it very clearly and make sure the spelling is correct!



• Do this for each part being labeled. Never cross the lines of labels. This causes a great deal of confusion.

• When all the parts required have been labeled, write the title of the diagram in the upper right-hand corner of the paper. Underline the title, using a straight edge.

• Be sure to indicate a magnification power if a micro-

scope was used!

Pizza Lab Requirements (completed before handing in lab!)
1. Two drawings of the pizza slides should have been completed —one of a low magnification and one of a high magnification.

2. The following parts should have been labeled:
- Pan
- Onion
- Anchovy
- Artichoke heart
- Sausage slices
- Pepper
- Broccoli
- Sun dried tomato
- Crust
- Pepperoni slices

3. Be sure the drawings have titles!

4. Answer the following questions:
- During the pizza lab, the move from low power of magnification was simulated. Describe how this change in magnification affected what you saw of the pizza.
- How would this affect a diagram of, say, a group of cells when drawing them using both 100X and 400X during a lab activity?

5. You will complete one additional diagram of their choice as part of this activity. Find something simple to draw, small enough that it isn't frustrating to sketch. Consider objects like an insect, a small house plant, a shell, a leaf, etc. Be sure to label any parts that can be identified and title the diagram.

HELPFUL HINTS

Students have made many positive comments about this activity. It gave them confidence in their own abilities and knowledge about what the teacher expects a diagram to contain. This activity has been used successfully in both standard level Biology I class as well as the honors level Biology II class.

In Biology I, the activity is done toward the beginning of the year, before doing microscope work. It will help to do a fair amount of microscope work after the pizza lab to reinforce drawing techniques learned and to give students further feedback. In Biology II, this activity is done before beginning a unit on histology, where students are asked to study a number of slides of human tissue.

The book, *Drawing on the Right Side of the Brain,* by Betty Dawson may give teachers more ideas for exercises that can help students gain skills and confidence in their drawing abilities.

SUMMING UP

I would love to hear from teachers who decide to use this activity and would especially like to know what worked for these teachers and their classes. Hopefully, cries of "I'm NOT an artist!" will be gone forever!

Food for Thought -The Cookie Analogy

Susan Johnson
Madison, Wisconsin

"Food for Thought – The Cookie Analogy" was originally written to introduce a unit on heredity at the high school level. It can easily be adapted for other grade levels or to include other topics. This is an activity in which the familiar is used to explain the unfamiliar. The familiar, in this case, would be cookies and cookie recipes, while the unfamiliar would be biological concepts/terminology, including gene, allele, heredity, environment, genotype, phenotype, adaptation, evolution, continuity, diversity, mutation, mutagen, teratogen, taxonomy and classification.

OBJECTIVES

Students often memorize information without understanding it. One of the reasons that this occurs is that they have little previous experience with basic biological concepts and, therefore, find them abstract and difficult to understand. In this activity, the familiar becomes a model that can be used to help students construct meaning for those concepts which often prove to be difficult to learn. It can also be used to help students construct meaning for terms that may be commonly used but often misunderstood.

MATERIALS

- Paper plates
- Napkins
- Paper cups
- Milk
- Cookies
- "Questions for the Baker" worksheets
- "Discussion Questions" worksheets
- Recipes for four kinds of cookies

PROCEDURE FOR THE TEACHER

Before the lab – As part of the activity, the students are given the assignment to bake one of four cookie recipes distributed to the class and to bring 1 dozen cookies to school. Several days should be allowed before the date of the classroom portion of the activity to provide adequate time to obtain ingredients and do the baking.

The students are asked to fill out the "Questions for the Baker" at the time the cookies are made and bring the completed worksheet to class along with 1 dozen cookies. The questions on the worksheet were designed to allow the recording of data that may prove useful in answering the "Discussion Questions" during the classroom portion of the activity.

Day of the lab – It is recommended, for several reasons, that the activity be done in small groups of 2-4 students. The enjoyable tone of the lab that begins with the unusual occurrence of bringing cookies to class continues to be evident in the groups as the students work on the discussion questions. Working on the questions within a group also expands the potential for ideas and interpretations, which are later shared with the entire class.

At the beginning of the activity, each student should put his/her cookies on a plate and then place the plate in the group of plates containing cookies baked from the same recipe. The four different groups of cookies can be situated around the room during Part I so that there will not be too many students working in one area. In their groups, they can move from one group of cookies to another as they answer the questions in Part I of the "Discussion Questions." Each group needs to fill out only one set of questions.

After about 5-10 minutes, they can begin Part II. To do so, each group should get an empty plate and collect one cookie from each of the plates of cookies. They can find a place to sit and work on the questions in Part II. Again, each group needs to fill out only one set of questions.

This is a good time to pass out the cups and pour the milk. The student groups can enjoy the cookies and milk while they consider the Part II questions.

About 15 minutes should be allowed for the groups to work on the Part II questions. Instruct them to use their time wisely so that they are not left with most of the questions and only a few minutes in which to answer them. The rest of the class period can then be used to go over the questions with the entire class.

POINTS FOR DISCUSSION

The following points should be emphasized during the time allotted for class discussion:

• The ingredients of the four recipes have been selected for specific reasons. For example, the two cookies (oatmeal raisin and oatmeal chocolate chip) that have the most similar phenotypes (appearances) actually differ the most in terms of their recipes or genotypes (genetic makeup). The relationship of having a similar appearance and very different recipe is analogous to the relationship between the black and panda bear. In appearance, both bears look similar. However, each has a very different DNA "recipe."

• Many biology teachers have experienced frustration when, at the end of a well planned unit on genetics, the students are still confused about the meaning of genetic concepts and terminology. This activity can be used to introduce and/or support all of the following concepts/terminology: gene, allele, heredity, environment, genotype, phenotype, adaptation, evolution, continuity, diversity, mutation, mutagen, teratogen, taxonomy and classification.

• Margarine, butter, and shortening can be used as examples of alleles (forms of a gene). The value of the analogy becomes more evident as it is applied to help the student construct meanings for concepts that are unfamiliar to his/her daily experience and, therefore, difficult to understand. At many times in class discussion — days or weeks following this activity — the familiar, concrete example can support the unfamiliar, difficult concept.

PROCEDURE FOR THE STUDENT

What types of questions are asked by those trying to unravel the mystery of life on Earth? As explorers traveled the globe and returned with great numbers of different organisms, many questions must have been posed as to the significance of the great variety of species and about how this variety might have occurred. How could this diversity mesh with the idea of "like begetting like?" Was change a part of the picture, and if so, how did it occur?

This activity will help begin to address questions such as those above, starting with a simple example, but something with which all students are familiar — COOKIES! And, to make cookies a part of "life" on Earth, for the purpose of this activity, they will be declared a species with the name *Crustula suavia*, Latin for "cookie sweet."

Each class member is assigned to bake cookies, following one of the four recipes provided. Each recipe makes several dozen cookies, some of which can be shared with family and/or friends, but 1 dozen must be brought to school on the day the assignment is due. While making the cookies, answer the questions on the "Questions for the Baker" worksheet. Bring it to class with the cookies, as it may be helpful in answering the "Discussion Questions."

Recipe #1

2 1/4 cups all purpose flour
1 teaspoon baking soda
1 teaspoon salt
1 cup margarine or butter
3/4 cup sugar
3/4 cup firmly packed brown sugar
1 teaspoon vanilla
2 eggs
1 package (12 oz.) chocolate chips

Preheat oven to 375° F. Beat together margarine, sugar, brown sugar, and vanilla until creamy. Beat in eggs. Combine flour, baking soda, and salt. Gradually add to margarine mixture. Stir in chocolate chips. Drop by rounded teaspoonfuls onto ungreased cookie sheets. Bake for 8-11 minutes.

Recipe #2
1 1/2 cups all purpose flour
1 teaspoon baking soda
1 teaspoon salt
1 teaspoon cinnamon
1/4 teaspoon nutmeg
1 1/4 cups margarine or butter
1/2 cup sugar
3/4 cup firmly packed brown sugar
1 teaspoon vanilla
1 egg
3 cups oats
1 cup raisins

Preheat oven to 375° F. Beat together margarine, sugar, and brown sugar until creamy. Beat in egg and vanilla. Combine flour, baking soda, salt, cinnamon, and nutmeg. Gradually add to margarine mixture. Stir in oats and raisins. Drop by rounded teaspoonfuls onto ungreased cookie sheets. Bake 8-11 minutes.

Recipe #3
1 1/2 cups all purpose flour
1 teaspoon baking soda
1 teaspoon salt
1 1/4 cups margarine or butter
1/2 cup sugar
3/4 cup firmly packed brown sugar
1 teaspoon vanilla
1 egg
3 cups oats
1 package (12 oz.) chocolate chips

Preheat oven to 375° F. Beat together margarine, sugar, and brown sugar until creamy. Beat in egg and vanilla. Combine flour, baking soda, and salt. Gradually add to margarine mixture. Stir in oats and chocolate chips. Drop by rounded teaspoonfuls onto ungreased cookie sheets. Bake 8-11 minutes.

Recipe #4
2 3/4 cups all purpose flour
2 teaspoons cream of tartar
1 teaspoon baking soda
1/2 teaspoon salt
1 cup shortening, margarine, or butter
1 1/2 cups sugar
2 eggs

Preheat oven to 350° F. Beat together margarine and sugar. Beat in eggs. Combine flour, cream of tartar, baking soda, and salt. Gradually add to margarine mixture. Roll into balls the size of walnuts. Roll into a mixture of 3 tablespoons sugar and 2 teaspoons cinnamon. Bake 12-15 minutes.

(See "Questions for the Baker" and "Discussion Questions" worksheets at the end of this activity.)

HELPFUL HINTS

• As teenagers are often known to consume milk by the gallon, use small paper cups. The 3-ounce size may be too small, but there are other sizes between 3 ounces and 8 ounces. It is recommended that the teacher pour the milk so that it can be distributed evenly.

• Although a majority of students may wish to make a particular recipe, such as the ever-popular chocolate chip cookie, each of the four recipes should be equally represented. It is interesting to note, however, when the cookies arrive for the lab, that an oatmeal raisin batch of cookies has been known to have mysteriously changed into a chocolate chip batch.

• Timing of the lab is important. It can be done in one class period, but the pace is very important. If you have to rush through the discussion of the questions, it defeats the objectives of the lab. Having some time

during a second class period for further discussion may be helpful.

• The value of this activity increases exponentially as it is adapted to a particular classroom. One variation to the activity that has already been tried was to ask a separate group of students to bake one of the recipes but to add only half of the recommended amount of an assigned ingredient -- or to leave an assigned ingredient out entirely. These changes in the amounts of certain ingredients could vary from not being very "harmful" to being "lethal," depending on their importance to the "survival" of the cookie.

• Another variation that has been tried has been to make the cookies at school with the cooperation of the home economics department, while a third variation used has been to make "no-bake" cookies at school. The use of commercially prepared cookies could be an interesting variation as there can be a number of varieties of basic cookies such as chocolate chip. There is also a wide variety of cookies in general, as evidenced by the shelf space taken up in the cookie section of most grocery stores, and this variety includes some very unusual cookies as well.

Assignment

Group members _____

Date _____

Questions for the Baker

1. Which recipe (Number One, Two, Three, or Four) were you assigned? _____
2. (a) What brand of flour did you use? _____
   (b) Was it bleached or unbleached? _____
3. (a) Did you use shortening, margarine, or butter? _____
   (b) What brand? _____
   (c) Was the source animal or vegetable? _____
4. If you used vanilla, was it real or artificial? _____
5. Were the eggs small, medium, large, or extra large? _____
6. (a) What brand of sugar did you use? _____
   (b) What, if anything, did the package say as to its degree of granulation? _____
7. If you used oats, chocolate chips or raisins, what brand and/or type did you use?
   (a) oats _____
   (b) chocolate chips _____
   (c) raisins _____
8. How long did you bake the cookies? _____
9. (a) Did you vary the recipe in any way? _____
   (b) If yes, what variation did you make? _____

Discussion Questions

Group members _____

Date _____

Part I

Arrange your cookies on the plate provided by your teacher and put the plate next to the other plates of cookies baked from the same recipe. Resist temptation and refrain from eating any cookies until you are otherwise instructed. Working in your group, answer the questions in Part I and have one person from your group record the answers. Wait until all groups have had a chance to answer the questions in Part I before going on to Part II.

1. Do all the cookies on any given plate come from the same recipe?

2. Upon close examination, do all the cookies on any given plate look identical?

3. What similarities, if any, do you observe?

4. What differences, if any, do you observe?

5. Of any group of plates containing cookies from the same recipe, are the cookies identical from plate to plate?

6. What similarities, if any, do you observe?

7. What differences, if any, do you observe?

Part II

Each group should obtain an empty plate. Place one cookie from every one of the plates of cookies on the new plate. Find a place in the room where you can continue to make cookie observations. Working in your group, answer the questions in Part II. Have one person from your group record your answers. As you work on the questions feel free to begin an in-depth enzymatic analysis of the cookies on your plate.

1. What are possible reasons why all the cookies baked by the same individual might not be identical?

2. What are possible reasons why all the cookies baked by different individuals, using the same recipe, might not be identical?

3. Is there more than one recipe in existence for chocolate chip cookies? Why or why not?

4. Using the cookies as examples, can you always tell by looking at a group of different organisms which had the most similar "recipes"? Explain your answer.

5. (a) Why isn't there only one recipe for cookies?

   (b) How might recipes come to change from one generation of bakers to the next?

   (c) Would any change in a recipe be as "fit" or beneficial as any other and what might determine its "fitness"? Give reasons for your answer.

6. (a) Can you think of cookies that seem to be specific to one ethnic group or geographic location? If yes, give an example.

   (b) Why might this be?

7. (a) If you were asked to divide these four representatives of the cookie species on the plate into three groups, such as we divide species into varieties or breeds, what would these groups be?

   (b) What was your rationale for grouping them the way that you did?

8. Which recipe was most different from the others? What made it seem different?

(When the groups have finished the cookie questions, we will get back together as a class to share our thoughts.)

Section VIII - Botany

Project Genesis - A Cooperative Learning Experience

Robert Villanti
Sayville, New York

"Project Genesis" is a hands-on, cooperative learning experience for students who have completed the botany portion of their biology course.

OBJECTIVE

As a team with well-defined, rotating roles, the students will visit five stations, each dealing with a particular aspect of plant anatomy and physiology. Each team is given a set of specific biological and physical conditions for an imaginary planet, and working within these boundaries, the research team will engineer a plant species that will survive within that environment.

GRADE LEVEL

Grades 10-12

MATERIALS

Station I – Root Station

- Specimens of various root systems (fibrous, taproot, storage, rhizoids on microscope slide).
- Reference text.
- Microscope (for rhizoids).

Station II – Stem Station

- Photographs or samples of several varieties of woody and herbaceous stems.
- Microscope setups with cross-sections of monocot and dicot herbaceous stems.
- Microscope setup with cross-sections of woody stem tissue.
- Woody stem cross-section with labeled tissues and chart describing tissue function.
- Reference text.

Station III – Leaf Station

- Diagrams, photos, or samples of a variety of leaf shapes.
- Microscope setup with cross-section of leaf anatomy.
- Cutouts of leaf tissue layers (cuticle tissue of varying thicknesses, upper epidermis, palisade layer, spongy layer, lower epidermis — several representations with different numbers of stomatal openings in each).
- Transparent tape.
- Reference text.

Station IV – Biochemistry Station

- Reference text.
- Several vials of food coloring mixture to mimic various pigment combinations of chlorophyll, carotene, and xanthophyll.
- Chart of percentage of each pigment found in the vials.
- Photographs showing the variety of structural adaptations made by insectivorous plants.

Station V – Defense Station

- Reference text.
- Photographic or actual sample representations of plant defense strategies.

PROCEDURE FOR THE TEACHER

Before the lab – Discussion must include how a successful, cooperative learning model operates. This discussion should contain the following points:

- Each member of the team has a specific task to perform at each station. These roles are outlined in the introductory material of the lab.
- Each role changes as the team rotates to each station. This insures that all students are operating within each capacity.
- Absolutely no one individual is in power or control over the rest of the students in the group. Each role is equally important.
- One person in each group is elected to be the spokesperson during the post-lab discussion.

Day of the Lab – The instructor assigns each group to a station and is the time keeper for the length of stay at each station. It is suggested that two lab periods are used to complete this lab, with approximately 10-15 minutes spent at each station.

HELPFUL HINTS

Upon close inspection of the imaginary planets, it is obvious that the biological and physical conditions mimic the major biomes of Earth. Connections to this lab when studying the biomes will enable the learning process to be more effective. A major aspect of this lab is to foster creativity on the part of the student teams. To better enable this, allow the students to add some biological/physical conditions to the assigned planet themselves. It must be clear in the minds of the students that any added conditions must not conflict with those that are already present.

SUMMING UP

Post-lab discussion should include an oral presentation by the spokesperson about the assigned planet and the plant their genesis team has constructed to suit the environment on the assigned planet.

SAMPLE MEMO TO EACH TEAM

TO: Science Team Members
FROM: Headquarters; Project Genesis
RE: Plant Colonization

Your team has been selected for the delicate mission of generating the first form of plant life to inhabit the planet **Karila**. To accomplish this, each member of the your team will fill a variety of roles. The functions of each role are described below. We, at project Genesis, wish you the best in your endeavor.

Plant Biologist - This person will, upon consultation with the others, determine if a favorable structure/ function relationship exists within the proposed plant parts.

Environmentalist - All environmental conditions that will affect the growth, development, and ability to survive will be presented to the group by this individual.

Botanical Artist - Any and all schematics (diagrams, models, etc.) called for througout any portion of the Genesis Project will be the responsibility of this individual.

Research Botanist - This person will be used as a source of reference to all in presenting factual data to help solve the particular challenge in question.

NOTE - IT IS IMPERATIVE THAT THE ROLES ARE INTERCHANGED AT EACH STATION!!!!!!!!

TO: Science Team Members
FROM: Headquarters, Project Genesis
RE: Assignment

Welcome to your planet! This planet has been carefully chosen for you to begin your plant colonization experiments. Below are a list of physical and chemical conditions that are vital to your efforts. Good luck!

KARILA
Temperatures - 10 degrees F all the time
Daylight - seasonal (2 hours to 24 hours)
Rainfall - low
Snowfall - very high
Soil - permanently frozen
slightly acidic (pH 6.5)
poor drainage ability
rock layer approximately 60 ft. below surface
Topography - relatively flat with some surface rocks
Atmospheric conditions - Nitrogen-60%
Oxygen-18%
Carbon Dioxide-9%
Other-13%
Animal life - small animals (herbivores)
hawks

TO: Science Team Members
FROM: Headquarters, Project Genesis
RE: Assignment

Welcome to your planet! This planet has been carefully chosen for you to begin your plant colonization experiments. Below are a list of physical and chemical conditions that are vital to your efforts. Good luck!

GEMON
Temperatures - 94 degrees F daytime; 40 degrees F night
Daylight - 12 hours on a 24 hour scale
Rainfall - moderate (60 cm per year)
Snowfall - none
Soil - high levels of organic material with large amounts of hydgrogen sulfide
constantly wet with small pools
acidic (pH 5.5)
poor drainage ability
rock layer approximately 60 ft. below surface
Topography - relatively flat with some bog-like conditions
Atmospheric conditions - Nitrogen-80%
Oxygen-18%
Carbon Dioxide-1%
Other-1%
Animal life - breeding insects
snakes

TO: Science Team Members
FROM: Headquarters, Project Genesis
RE: Assignment

Welcome to your planet! This planet has been carefully chosen for you to begin your plant colonization experiments. Below are a list of physical and chemical conditions that are vital to your efforts. Good luck!

OVION
Temperatures - 94 degrees F daytime; 40 degrees F night
Daylight - 16 hours on a 24 hour scale
Rainfall - small (less 30 cm per year)
Snowfall - none
Soil - low levels of organic material with large amounts of pulverized quartz
neutral (pH 7.0)
excellent drainage ability
rock layer approximately 60 ft. below surface
Topography - relatively flat with some canyons
Atmospheric conditions - Nitrogen-20%
Oxygen-70%
Carbon Dioxide-4%
Other-6%
Animal life - reptiles
owls and small birds
insects with exoskeletons

TO: Science Team Members
FROM: Headquarters, Project Genesis
RE: Assignment

Welcome to your planet! This planet has been carefully chosen for you to begin your plant colonization experiments. Below are a list of physical and chemical conditions that are vital to your efforts. Good luck!

CYLONIA
Temperatures - constantly 78 degrees F
Daylight - 12 hours on a 24 hour scale
Rainfall - excessive (250 cm per year)
Snowfall - none
Soil - rich in organic material with small amounts of hydrogen sulfide
neutral (pH 7.0)
poor drainage ability
rock layer approximately 10 ft. below surface
Topography - relatively flat
Atmospheric conditions - Nitrogen-70%
Oxygen-20%
Carbon Dioxide-8%
Other-2%
Animal life - sucking insects
small populations of larval insects in pools

TO: Science Team Members
FROM: Headquarters, Project Genesis
RE: Assignment

Welcome to your planet! This planet has been carefully chosen for you to begin your plant colonization experiments. Below are a list of physical and chemical conditions that are vital to your efforts. Good luck!

TOLDAR

Temperatures - cold season (6 mos.): 20 degrees F to -30 degrees F
warm season (6 mos.): 60 degrees F to 70 degrees F
Daylight - 8 to 12 hours on a 24 hour scale
Rainfall - abundant
Snowfall - 4 - 6 feet per year
Soil - rich in organic material
slightly acidic (pH 6.8)
fair drainage ability
rock layer approximately 5 ft. below surface
Topography - mountains and valleys
Atmospheric conditions - Nitrogen-85%
Oxygen-6%
Carbon Dioxide-4%
Other-5%
Animal life - rodents (seed eaters)
large mammals (herbiovers)
predators

ROOT STATION

I. Root Type

A. Choose from the collection of root types shown, the root system most suited to your planet's environment. If the desired root system is not shown, please describe your choice.

1. Which type of root system did your team choose?

_____

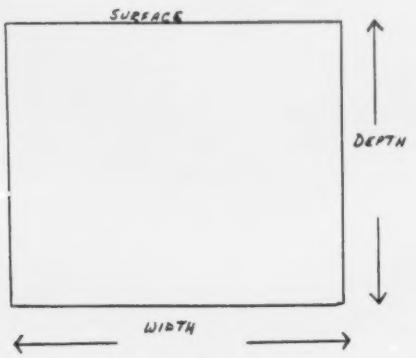
2. Offer a brief explanation as to WHY this particular root system was chosen.

_____

_____

_____

3. In the space provided, draw the particular root system chosen and give an indication of its depth and area it occupies.



II. Root Function

A. Roots can provide a variety of functions for plants dependent upon the environmental pressures that exist within a particular area. To clarify the functions your team wishes for its root system to display, perform the rank order exercise below.

1. Using a "1" to indicate the most important characteristic of your root system and a "4" to indicate the least, rank order the functions below.

____ a) Anchorage
____ b) Absorption
____ c) Reproduction
____ d) Food Storage

2. What other qualities would your root system possess? Choose from the list below and write your choice(s) to the left of the diagram drawn for #3.

a) Hydrophilic
b) Active transport ability
c) Salt tolerance
d) Adventitious support roots
e) Other (Be Creative!)

STEM STATION

I. Stem Type
A. Choose from the collection of stem types shown, the stem type that best suits your particular planet's environmental conditions. If the particular stem type your team wants is not represented, please describe your choice.
1. Which stem did you choose?

_____

2. Briefly explain WHY your team chose a particular stem type.

_____

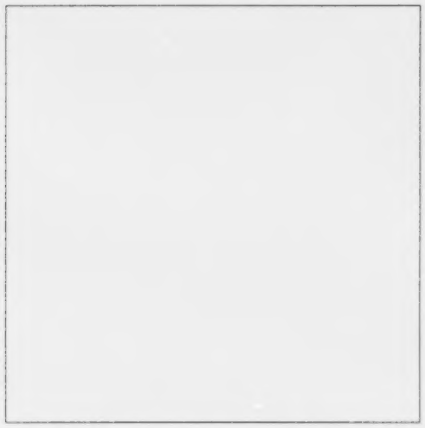
_____

_____

3. Make a drawing of the stem type chosen and give an indication of its mature height and diameter.

Mature height ____

Mature diameter ____



II. Herbaceous Stems (NOTE: Complete only if your chosen stem is herbaceous.)
A. Review the slides provided at your stem station of monocot and dicot herbaceous stems.
1. Is your herbaceous stem a monocot, dicot or an original creation?

_____

2. How does your stem's vasculature compare to those shown? BE SURE TO EXPLAIN WHY YOUR CHOICE WAS MADE!

_____

_____

_____

3. Draw and label a cross section of the stem you chose in the space provided below.

III. Woody Stem (NOTE: Complete this portion only if the stem chosen is woody, or has woody qualities.)

A. A variety of woody stems can be distinguished from each other dependent upon the arrangement and thickness of each type of tissue layer.

1. What is the order of tissue layers in your stem from the center of the stem to its outer covering?

_____

_____

_____

_____

2. In the space provided below, draw a representative cross section of your woody stem. Indicate the relative thickness of each layer of tissue in your stem. BE PREPARED TO DEFEND YOUR CHOICES!

LEAF STATION

I. Leaf Shape

A. A multitude of leaf shapes can be found within the plant kingdom. From the diagrams provided at the leaf station, choose the leaf that will best suit your plant creation. If a desired leaf shape is not present, draw your creation.

1. What leaf shape did your team choose? (If an original creation, write "NONE.")

2. Draw a rough diagram of the leaf shape chosen in the space below, and provide a brief explanation as to WHY this particular shape was chosen.

II. Leaf Anatomy

A. Observe the slide of a typical leaf cross section of a planet found on Earth. Keep in mind that each layer has a particular function.

1. What tissue layers would your plant leaf contain?

2. Using the cut-outs provided at your leaf station, make a cross section diagram of your leaf's internal and external structure. Tape the layers to the paper below.

III. Leaf Functions

A. Leaves serve a variety of functions to enable a plants survival within a particular environment. Anatomical features are reflected in the performance of these functions.

1. For each layer of tissue chosen in your leaf cross section, provide a brief statement as to WHY it was chosen for your particular environment.

BIOCHEMISTRY STATION

I. Modes of Nutrition in Plants

A. Many methods of obtaining nutrients exist within the plant world. Several variations of synthesis reactions exist within the processes of photosynthesis and chemosynthesis. Insectivorous plants supplement synthesis modes of nutrition with the rich supplies of minerals found within insect bodies.

1. Decide which mode or modes of nutrition that would best suit your plant creation in its particular environment and write your choice(s) in the space below.

_____

II. Photosynthesis (NOTE: Complete this category only if you chose photosynthesis above.)

1. If a synthesis reaction is chosen, what raw materials would be needed?

_____

_____

2. Observe the vials of colored solutions at your station and choose the one(s) that would best mimic the pigment you would like your plant to contain. Write your choice(s) in the space below and explain how it will work for you in your particular environment.

_____

_____

_____

3. If your plant is photosynthetic, please write what the general reaction would need and produce. (BE SURE TO CONSULT YOUR PLANET DATA SHEET.)

_____

4. What pathway would your planet creation use for its dark reactions? WHY?

_____

_____

III. Chemosynthesis (NOTE: Complete this category only if you have chosen chemosynthesis above.)

1. Describe what compounds you have found in the soil that when oxidized would provide the energy needed to "run" the synthesis reactions. (BE CREATIVE!)

_____

_____

2. Write a general chemical reaction that will show the raw materials and end products of your synthesis reaction.

_____

IV. Insectivorous or Other (NOTE: Complete this section if you have chosen this option above.)

1. What structural changes will have to be made to your plant to accomodate attracting and trapping its prey? _____

2. How does your plant creation digest its prey? (PLEASE BE SPECIFIC!)

V. Sythesis of Other Molecules (ALL PARTICIPANTS COMPLETE THIS SECTION.)
1. From the list below, indicate the amout of production and what each would be used for by your plant.
a. Starch
b. Lipids
c. Proteins
d. Other

DEFENSE STATION

I. Methods of Defense
A. Although plants may appear harmless, several physical, chemical and behavioral defenses can and do exist. Observe the examples provided that illustrate some of the defensive strategies exhibited by plants.
1. Choose from the list below which defense or defenses you would like your plant to have. Place a check mark next to your decisions.
___a. Toxins
___b. Leaf folding
___c. Thorns
___d. Sticky hairs
___e. Slick surfaces
___f. Narcotic nectar
___g. Offensive odors
___h. Traps
___i. Other (BE CREATIVE!)
2. Indicate how the defenses your team chose are carried out. Be sure to include what structural modifications are necessary.

Fruit Lab

Mary R. Chappell
Virginia Beach, Virginia

This lab will allow the students to conduct an examination of various fruits to determine what part of the flower develops into a fruit. Analysis of the fruits will also help students to predict how seeds of various fruits are distributed.

OBJECTIVE

The objective of this lab is to identify types of fruit, to determine what part of the flower develops into edible fruit, and to determine the means of seed dispersal based on the characteristics of the fruit.

MATERIALS

A variety of fleshy and dry fruits, a variety of containers to hold each fruit, and a set of fruit lab cards.

PROCEDURE FOR THE TEACHER

Before the lab

• Make a set of fruit cards. Set up the lab by using one of each type of fruit with its corresponding card per class. Teachers may use more than one of some fruit cards. (For example, two cards will be needed to represent a drupe if a peach and a cherry are used.) Using one set of cards, place the fruits and their corresponding cards on tables (desks) around the room. Students will move around the room to each fruit. (Cards are found at the end of the activity.)

• One fresh pineapple per class serves as a nice snack after the explanation of why it is a multiple fruit. This will be the first opportunity for tasting fresh pineapple for some students.

• Use some fleshy and some dry fruits.

Suggested fruits to use are the following:
Drupe ... peach, cherry, plum, coconut
Pod ... peas, beans
Berry ... tomato, grape
Modified berry ... cucumber, citrus fruits, squash, kiwi, banana
Achene ... dandelion, sunflower
Nut ... hazelnut, pecan, acorn
Aggregate fruit ... raspberry, blackberry
Capsule ... iris, lily
Grain ... corn, oats, wheat
Multiple fruit ... pineapple
Accessory fruit ... strawberry
Pome ... apple, pear
Samara (winged fruit) ... maple

Day of the lab

• Place one of each fruit and fruit card to be used in a culture bowl, petri dish, or similar container; distribute around the classroom tables/desks; and allow students to move from one station to another station.

• Remind the students not to eat the fruit from the setup.

PROCEDURE FOR THE STUDENT

List the name of each fruit available and fill in the Data Chart following this activity with the requested information. Then go on to answer the questions listed below:

Analyses and Conclusion Questions:

1. A fruit is the _____ _____ of a flowering plant.
2. Why is it important for seeds to be dispersed?
3. What role does the fruit have in seed dispersal?
4. List three ways that seeds are dispersed.
5. Why are cucumbers, tomatoes, and beans considered fruits?
6. What part of the peanut is eaten?
7. Which fruits studied are likely to have their seeds dispersed by the ovary wall bursting open?
8. Which fruits studied are more likely to have their seeds dispersed by animals?

HELPFUL HINTS

- Provide a reference chart on fruit.
- Save acorns, maple seeds, wheat, locust pods, and so forth, from one year to the next by keeping them in the refrigerator.
- Check with the produce manager of a grocery store to see if it is possible to get donations of blemished fruit to use at no cost. By using only one specimen of each fruit type and having students rotate stations, the total cost is low.

Answers to questions:

1. Ripened ovary.
2. It is important for seeds to be dispersed to prevent overcrowding and to carry the plant to other favorable environments.
3. The fruit attracts animals who eat the fruit.
4. Animals, environmental forces (wind and water), and self dispersal.
5. They contain seeds.
6. Seed.
7. Ovary walls of dry fruits burst and propel the seed away from the fruit. Examples are pods and capsules.
8. Sweet, fleshy fruits; dry fruits, such as nuts; dry fruits that have hooks on them.

SUMMING UP

List other examples of each type of fruit studied. List other parts of the plant that may be edible.

(See "Fruit Reference Chart" and "Fruit Lab Cards" on the following pages.)

Data:

Name of Fruit	Type of Fruit	Dry or Fleshy	Simple or Compound	Edible Part of Flower	Means of Dispersal

Analyses and Conclusion Questions:

1. A fruit is the _____ _____ of a flowering plant.
2. Why is it important for seeds to be dispersed?
3. What role does the fruit have in seed dispersal?
4. List three ways that seeds are dispersed.
5. Why are cucumbers, tomatoes, and beans considered fruits?
6. What part of the peanut do you eat?
7. Which fruits studied are likely to have their seeds dispersed by the ovary wall bursting open?
8. Which fruits studied are more likely to have their seeds dispersed by animals?

HELPFUL HINTS

1. Reference chart on fruit follows.
2. Save acorns, maple seeds, wheat, locust pods, and so forth from one year to the next by keeping them in the refrigerator.
3. If you check with the produce manager of a grocery store, you may be able to get some donations of blemished fruit to use at no cost. By using only one specimen of each fruit type and having students rotate stations, the total cost is low.

Fruit Reference Chart

Type	Description	Examples	Dry/Fleshy	Simple/ Compound
Berry	ovary fleshy; thin skinned with many seeds	tomato grape	Fleshy	Simple
Drupe	ripened ovary 2-layered outer, fleshy; inner, hard forming pit or stone	peach coconut cherry plum	Fleshy	Simple
Modified berry	tough covering	cucumber lemon	Fleshy	Simple
Pome	fleshy part from receptacle and calyx; ovary forms core	apple pear	Fleshy	Simple
Accessory fruit	receptacle edible; seeds form from many pistils and are on outside	strawberry	Fleshy	Compound
Aggregate fruit	drupes on outside of receptacle fromed from many pistils on one flower	blackberry raspberry	Fleshy	Compound
Multiple fruit	cluster of fruit grown close together	pineapple fig mulberry	Fleshy	Compound
Capsule	ovary has several chambers with many seeds; splits when ripe	lily iris cotton	Dry	Simple
Pod	thin-walled, single-chambered ovary; many seeds; splits when ripe	beans peas	Dry	Simple
Achene	ovary wall separate from seed	sunflower	Dry	Simple
Grain	ovary wall firmly fastened to single seed	corn oats wheat	Dry	Simple
Nut	hard ovary wall enclosing a single seed	acorn pecan	Dry	Simple
Samara	winged fruit	maple	Dry	Simple

Fruit Lab Cards

Drupe
A drupe is a fleshy fruit. The repened ovary is two-layered with the outer layer being fleshy and the inner layer hard, forming a stone or a pit. The seeds are distributed by animals.
Observe the following:
1. fleshy layer of the ovary
2. stony layer of the ovary
3. seed

Pod
A pod is a dry fruit. The ovary wall is thin with the seeds in single chambers. The pod contains several seeds, splits when ripe, and throws the seeds several feet.
Observe the following:
1. seed
2. ovary
3. ovary wall
4. sepals
5. pedicel

Berry
A berry is a juicy fleshy fruit with a thin skin and several seeds inside. The seeds are dispersed by animals.
Observe the following:
1. thin skin
2. ovary
3. seeds

Achene
This dry fruit has a thin ovary wall that is separated from the seed. The dispersal of the dandelion is by the wind.
Observe the following:
1. ovary wall
2. seed

Nut

The nut is a dry fruit that has a hard ovary wall enclosing a single seed. The seeds are dispersed by animals.

Observe the following:

1. ovary wall
2. seed

Grain

A grain is a dry fruit that remains closed when ripe. The ovary is thin-walled, and the seed is firmly attached to it. Seeds are dispersed by animals.

Observe the following: (Break open a grain.)

1. ovary wall
2. seed

Aggregate Fruit

Aggregate fruits are composed of many drupes in a cluster located in a single receptacle. Each drupe has an ovary that is two-layered. The outer layer is fleshy, and the inner layer is hard. The hard layer forms a stone, or pit, which contains the seed.

Observe the following:

1. the cluster of drupes
2. fleshy ovary outer layer

Capsule

The capsule is a dry fruit. The ovary has several chambers, each with many seeds. The seed splits open when mature.

Observe the following:

1. cross section to see chambers

Modified Berry

The modified berry has a fleshy ovary with a tough skin. The fruit contains many seeds. The seeds are generally dispersed by animals.

Observe the following:

1. ovary
2. ovary wall
3. seed

Multiple Fruit

A multiple fruit is a fleshy fruit formed from a cluster of flowers. Many single ovaries fuse to form a multiple fruit. The tips sticking out over the fruit are sepals. If you lift each sepal, you will see the stamen from the flower.

Observe the following:

1. fruit sections (representing a single ovary)
2. sepals
3. stamen

Accessory Fruit

The accessory fruit is a fleshy fruit that has many seeds spread over the edible receptacle. The seeds are dispersed by animals.

Observe the following:

1. receptacle
2. sepals
3. seeds

Pome

A pome is a fleshy fruit. The ovary forms a papery core. The receptacle forms the fleshy edible part of the pome. The seeds are dispersed by animals.

Observe the following:

1. receptacle
2. core
3. seeds
4. sepals
5. pedicel

Winged Fruit

The winged fruit is a dry fruit that has a thin ovary wall which separates from the seed. A wing is attached to the ovary wall. This wing is used for wind dispersal.

Observe the following:

1. wing
2. ovary wall
3. seed